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THE JOURNAL
OF
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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CONTENTS

SOCIETY AFFAIRS
Monthly Meetings: New York, November (3); Boston, November (3); St. Louis, November (4). Annual Meeting (4). Reports of Meetings: New York, October (5); San Francisco, October (6); St. Louis, October (7); Boston, October (7). John Fritz Medal Award (7). Charles T. Porter (8). Tribute to Dr. Raymond (9). Student Branches (10). Meeting of the Council (12). Necrology (15).

PAPERS
The Joint Meeting in England, Calvin W. Rice.................... 1695
Transmission of Heat in Surface Condensation, George A. Orrok... 1771
First Large Gas-Engine Installation in American Steel Works, E. P. Coleman.................... 1835

GENERAL NOTES.................... 1927
PERSONALS.................... 1932
ACCESSIONS TO THE LIBRARY.................... 1934
EMPLOYMENT BULLETIN.................... 1941
CHANGES OF MEMBERSHIP.................... 1944
COMING MEETINGS.................... 1950
CURRENT BOOKS.................... 1953
OFFICERS AND COMMITTEES.................... 1955

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THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 NOVEMBER 1910 NUMBER 11

COMING MEETINGS

MEETING IN NEW YORK, NOVEMBER 9

The regular New York meeting of the Society, which is ordinarily held on the second Tuesday of each month, will be held in November on the day following, i. e., Wednesday, November 9, since Election Day this year falls on the second Tuesday. The paper of the evening will be by Ellis Soper, Mem. Am. Soc. M. E., Detroit, Michigan, on the Rotary Kiln, published in The Journal for October, and there will be discussion by several engineers interested in the cement industry. Following this paper, Chas. Whiting Baker, Mem. Am. Soc. M.E., Editor of Engineering News, who was a member of the engineering commission which went to Panama with President Taft in 1909, will give an illustrated lecture on the subject of the Panama Canal. Mr. Baker has many views of work in progress and will give the results of his personal observations during his visit to the canal zone.

MEETING IN BOSTON, NOVEMBER 10

The meeting in Boston on November 10 will be in charge of The American Society of Mechanical Engineers; the Boston Society of Civil Engineers, the Boston section of the American Institute of Electrical Engineers and the Boston Chamber of Commerce coöperating.

The meeting will be a topical discussion on Smoke Abatement in Boston, participated in by D. F. Randall, Mem. Am. Soc. M. E. and others, and will be held in the auditorium of the Edison Company, 39 Boylston Street.

MEETING IN ST. LOUIS, NOVEMBER 12

A joint meeting of the Society with the Engineers Club of St. Louis will be held in the Auditorium of the Engineers Club of St. Louis, 3815 Olive St., on November 12.

THE ANNUAL MEETING

The Annual Meeting of the Society will be held in New York December 6-9, 1910. The assignment of papers for the meeting will be made from those published in The Journal for October, November and December. The program for the meeting is in preparation and will be announced at an early date.

RAILROAD TRANSPORTATION NOTICE

Arrangements for hotel, transportation and Pullman car accommodations should be made personally.

For members and guests attending the Annual Meeting in New York, December 6-9, 1910, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

a Buy your ticket at full fare for the going journey, between December 2 and 8 inclusive, and get a certificate, *not a receipt,* securing these at least half an hour before the departure of the train.

b Certificates are not kept at all stations. If your station agent has not certificates and through tickets, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to S. Edgar Whitaker, office manager, at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after December 9.

d An agent of the Trunk Line Association will validate certificates, Dec. 7, 8, 9. No refund of fare will be made on account of failure to have certificate validated.

e One-hundred certificates and round trip tickets must be presented for validation before the plan is operative. This makes it important to show the return portion of your round trip ticket at Headquarters.

f If certificate is validated, a return ticket to destination can be purchased, up to Dec. 13, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.

Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur, Sault Ste. Marie Sarnia and Windsor, Ont.

REPORTS OF MEETINGS

MEETING IN NEW YORK, OCTOBER 11

New York monthly meetings of the Society were resumed on October 11, when a paper was presented by Frank B. Gilbreth, on Fires: Effects on Building Materials and Permanent Elimination. The meeting was held in the Engineering Societies Building with an attendance of 176.

The paper was discussed by J. P. H. Perry, of the Turner Construction Co., who emphasized the value of reinforced concrete in the construction of fireproof buildings, illustrating his remarks by a

number of lantern slides. H. deB. Parsons, consulting engineer, used an interesting series of slides to show the effect of fires on tall buildings. Ira H. Woolson, of the National Board of Fire Underwriters, called attention with the aid of the lantern, to the danger of present methods of building construction, especially as applied to apartments and dwelling houses, in which little or no attempt at fireproofing is made. F. A. Waldron, industrial engineer, used a number of slides to illustrate the advantages of reinforced concrete for factory buildings. P. H. Bevier, chief engineer of the National Fire Proofing Co., discussed the use of hollow tile; Wm. D. Grier, of the National Fire Protection Association, took up numerous phases of the use of fireproof material; and written discussion was offered by E. E. Seyfert, of Pittsburg; Chas. T. Main, of Boston, and C. A. P. Turner, of Minneapolis.

MEETING IN SAN FRANCISCO, OCTOBER 14

Under the direction of the Meetings Committee, the activities of the Society are developing in a way that is truly national. Meetings are held in various cities to enable members, many of whom can seldom attend the New York meetings, to strengthen their acquaintance among engineers and to participate in the discussion of papers. During the past year meetings have been held regularly in Boston, New York and St. Louis, and during the coming year they will also be held in San Francisco and probably other cities.

The initial meeting in San Francisco was held on October 14, when members of the Society resident in San Francisco and vicinity gathered at the Palace Hotel to effect an organization. Calvin W. Rice, Secretary, went out from New York for the purpose of meeting members in San Francisco, assisting in the organization and addressing the first meeting.

The gathering was a success in every respect. The local members were enthusiastic and it is believed that much good will result to those residing on the Pacific slope as well as to other members who will be benefited indirectly through the publication, in The Journal, of material upon important engineering work in progress in that section of the country. A. M. Hunt was elected Chairman and T. W. Ransom Secretary. Prof. W. F. Durand, E. C. Jones and Thomas Morrin will constitute the Executive Committee.

A resolution was adopted inviting the Society to hold its semi-annual meeting in San Francisco during the Panama-Pacific Expo-

sition in 1915 and the suggestion was made to the Council that an international meeting of mechanical engineering societies be held at the same time.

It is proposed to hold four local meetings in San Francisco annually.

MEETING IN ST. LOUIS, OCTOBER 15

At the meeting of the Society in St. Louis on October 15, the Engineers Club participating, the paper by Frank B. Gilbreth, on Fires: Effects on Building Materials and Permanent Elimination, was presented. W. H. Bryan presided and in the absence of the author the paper was presented by Prof. E. L. Ohle, Mem. Am. Soc. M. E., and was discussed by E. D. Meier, A. A. Aegerten, James Waterworth, Prof. H. W. Hibbard, W. H. Bryan, R. W. Maxton, G. R. Wadleigh, A. B. Greensfelder and others.

MFETING IN BOSTON, OCTOBER 19

The meeting in Boston on October 19 was conducted by the Boston Society of Civil Engineers; The American Society of Mechanical Engineers and the Boston section of the American Institute of Electrical Engineers coöperating.

Prof. Thomas A. Jaggar presented a paper on An Account of the Destruction of Carthego, Costa Rico, by Earthquake on May 4, 1910. Prof. Chas. M. Spoffard and Frank B. Gilbreth, Mem. Am. Soc. M. E., discussed the effects of earthquakes on different classes of structures with the aid of a number of views of the destruction caused by earthquakes in Carthego and elsewhere. The attendance was about 250.

THE JOHN FRITZ MEDAL AWARD FOR 1910

The John Fritz Medal was established by the professional associates and friends of John Fritz, Hon. Mem. Am. Soc. M. E., of Bethlehem, Pa., on August 21st, 1902, his eightieth birthday, to perpetuate the memory of his achievements in industrial progress. The Medal is awarded by a Board of sixteen, made up in equal numbers from the membership of the American Society of Civil Engineers, the American Institute of Mining Engineers, The American Society of Mechanical Engineers and the American Institute of Electrical

Engineers. It is awarded for notable scientific or industrial achievement, and there is no restriction on account of nationality or sex.

Awards of this medal to date have been made as follows:

The first (1905) to Lord Kelvin for his work in cable telegraphy and other scientific attainments.

The second (1906) to George Westinghouse for the invention and development of the air brake.

The third (1907) to Alexander Graham Bell for the invention and introduction of the telephone.

The fourth (1908) to Thomas Alva Edison for the invention of the duplex and quadruplex telegraph; the phonograph; the development of a commercially practical incandescent lamp; the development of a complete system of electric lighting, including dynamos, regulating devices, underground system protective devices and meters.

The fifth (1909) to Charles T. Porter for his work in advancing the knowledge of steam engineering and in improvements in engine construction.

The Medal for 1910 has been awarded to Alfred Noble, Mem. Am. Soc. M. E., for notable achievements as a civil engineer, and will be presented at a meeting to be held at the House of the American Society of Civil Engineers on the evening of Wednesday, November 30, 1910, at 8.30 p.m. All members of the four national societies and others who may be interested are invited to be present. Dr. Samuel Sheldon, Past-President, Am. Inst. E. E., now President of the Board of Award, will preside and addresses will be made by Isham Randolph, Mem. Am. Soc. C. E., of Chicago, Rossiter W. Raymond, Secretary Am. Inst. M. E., and others.

THE LATE WORK OF CHARLES T. PORTER

In The Journal for October appeared a short account of the important engineering services of the late Chas. T. Porter, which the profession recognized by presenting to him the John Fritz Medal in 1909. During the latter years of his life, Mr. Porter was in retirement, but he gave evidence from time to time that he had not altogether ceased his activities in the direction of improving the high-speed steam engine. In 1904 he presented to the Society four papers on an advanced form of high-speed engine, which he had built and tested, and, it is known that he hoped to complete a system of power development which would make it possible to obtain a horsepower on the evaporation of nine pounds of water per hour. Since his death

his sons have gathered together his papers and put them in the hands of H. F. J. Porter who, with George H. Barrus, was associated with Charles T. Porter in his latest work. The former has revived the association of Mr. Barrus in this work, and has also enlisted the coöperation of Admiral Melville, who was greatly interested while Chief Engineer of the Navy in what Mr. Porter had developed for marine service. It is hoped that some way may now be found to make available the work of Mr. Porter in perfecting the high-speed engine, to which he gave the last twenty-five years of his life.

TRIBUTE TO DR. RAYMOND

A committee of members of the American Institute of Mining Engineers and other friends, which last April gave a dinner to Dr. Rossiter Worthington Raymond, in commemoration of his seventieth birthday, have issued an elaborate book, bound in morocco and beautifully decorated, containing the proceedings of that occasion in full detail. The volume opens with The Grand Canyon, a poem by Dr. Raymond, followed by photographs and sketches typifying important activities in his career, and copies of many letters of congratulation and engrossed resolutions from other societies. Dr. Raymond has for 26 years been Secretary of the Institute.

STUDENT BRANCHES

Activities for the season of 1910–1911 have recommenced in the Student Branches of the Society, as is evidenced by the following reports:

The University of Missouri has just held its election of officers, as a result of which H. W. Price is president, E. G. Spargo, secretary-treasurer, and Osmer Edgar, corresponding secretary. At the meeting on October 8, H. W. Price read a paper on Testing Gas Engines, which was followed by a general discussion relative to methods of speed adjustments, percentage of speed variations allowed, valve setting, order of firing, method of governing, gas consumption allowable, relative economy of producer and natural gas, and clearances allowed for producer gas, natural gas and gasolene.

At Pennsylvania State College, the Student Branch elected as officers: W. E. Heibel, president; D. C. Minick, vice-president, G. M. Forker, secretary and J. A. Hasseler, treasurer.

The prospects for the year at Purdue University are exceedingly bright, 72 new members having been enrolled during the past month.

At the September 14 meeting of the Stanford University Mechanical Engineering Association, Prof. W. F. Durand, Mem.Am.Soc.M.E., gave a talk on Hydraulic Power Developments in Switzerland. On September 28, the following officers were formally installed: honorary chairman, Prof. W. R. Eckart, Jr., Mem.Am.Soc.M.E.; chairman, J. B. Bubb; vice-chairman, E. L. Ford; secretary-treasurer, H. H. Blee.

The Stevens Engineering Society of Stevens Institute has announced its lecture course for the season, providing for bi-monthly lectures by prominent men. Dr. A. C. Humphreys, Manager Am.Soc. M.E., and President of the Institute, opened the series on October 18 with an address on Membership in Engineering Societies. Those who will speak at future dates are: Irving E. Moultrop, Manager Am.Soc.M.E.; James P. Haney, Director of Art in the High Schools of New York City; Donald B. MacMillan, who accompanied Peary to the Arctic Zone· Harvey W. Wiley, Chief of the Bureau of Chemistry, U. S. Dept. of Agriculture; Rossiter W. Raymond, Past-President and

Secretary, A.I.M.E.; David T. Day, Chief of the Bureau of Mines and Mineral Resources, U.S. Geological Survey; Gardner F. Williams, Life Member, A.I.M.E., associated for 18 years with Cecil Rhodes in South Africa; James Douglass, Past-President, A.I.M.E.; John A. Bensel, Commissioner, New York Board of Water Supply, and President A.S.C.E.; Carl Hering, Past-President A.I.E.E.; Frederick H. Newell, Director, U.S. Reclamation Service; William Campbell, Associate Professor of Metallurgy, Columbia University; A. Stanley Mackenzie, Professor of Physics, Stevens Institute; and George E. Hulse, Chief Engineer, Safety Car Heating and Lighting Company.

H. B. Dirks, Mem.Am.Soc.M.E., spoke to the University of Illinois Student Branch on September 30, on the Joint Meeting of the Society in England, at which he was present.

The University of Wisconsin, Madison, Wis., has elected the following officers: A. MacArthur, chairman; K. Kraatz, vice-chairman; A. Wegner, corresponding secretary, F. W. Braasch, assistant secretary; R. S. Moore, treasurer. Professor Thomas, Mem.Am.Soc.M.E. and Professor Christie, Assoc.Mem.Am.Soc.M.E., gave informal talks at the meeting of October 5, on the preparation of discussions of papers published in The Journal, and on the Joint Meeting,.

At a dinner of the Student Branch of the Massachusetts Institute of Technology on October 13 plans were laid for a trip to Buffalo and Niagara Falls. Professors Lanza, Miller and Hayward of the department of Mechanical Engineering were the speakers for the evening.

The Council has authorized the establishment of a student branch at the Sheffield Scientific School, Yale University, under the name of The Yale Mechanical Engineers' Club, Affiliated with The American Society of Mechanical Engineers. The student branch now has a membership of 29, with W. Roy Manny as secretary.

MEETING OF THE COUNCIL

The regular Meeting of the Council was held on the afternoon of Tuesday, October 11, 1910, in the Society rooms, with Vice-President Baker in the chair. There were present Chas. Whiting Baker, George M. Bond, H. L. Gantt, Alex. C. Humphreys, James Hartness, I. E. Moultrop, H. G. Reist, F. M. Whyte, Wm. H. Wiley, Treasurer, Arthur M. Waitt, Chairman of the Finance Committee, and the Office Manager representing the Secretary. Regrets were received from W. F. M. Goss, E. D. Meier and R. C. Carpenter.

The minutes of the meeting of May 31 were read and approved. The Secretary reported the following deaths: Mark Bary, Chas. B. Clark, Barton Cruikshank, W. P. Bettendorf, W. E. Crane, J. D. E. Duncan, James B. Faulks, Chas. H. Ferry, C. E. Foster, Joseph Garbett, Jno. E. McKay, Albert Spies, Chas. T. Porter.

The following resignations were accepted: Thos. C. Perkins, Chas. E. Jones, R. B. Hart, Thos. Appleton, Frank R. Chambers, Jr., Warren S. Locke.

Notice was given of the purpose to elect to life membership under the provisions of C 23, S. B. Whiting of Cambridge, Mass., Charter Member of the Society, and of W. F. Mattes of Scranton, Pa.

Voted: To approve the appointment of Honorary Vice-Presidents: National Irrigation Congress, Pueblo, Colo., Sept. 26–30, C. H. Williams of Denver, Colo.; Second National Conservation Congress, St. Paul, Sept. 5–9, Paul Doty, J. J. Flather, L. H. Gardner, E. E. Johnson and M. E. R. Toltz; Inauguration of President McVey, University of North Dakota, Grand Forks, Prof. Calvin H. Crouch; American Mining Congress, Los Angeles, Cal., Sept. 26-Oct., 1. H. H. Clark and Robert Linton; Funeral of Charles T. Porter, Honorary Member, Alex. C. Humphreys, Hosea Webster, A. E. Forstall and J. E. McIntosh.

Voted: To confirm the action of the Executive Committee in declining under the provisions of C 56 the request of the Good Roads Association to participate with them in the securing of legislation favorable to promoting the improvement of public highways for interstate travel, military uses, etc., as provided in H. R. Bill 25,333 introduced by Representative Cocks.

Voted: To confirm the action of the Executive and Finance committees as outlined in the letter of the Secretary, July 5, 1910, approving an additional appropriation of $3500 for the Publication Committee, and the transfer of $300 from the Power Tests Committee to the Meetings Committee.

Voted: To approve the list of candidates recommended for the several grades of membership, as given in the minutes of the Membership Committee Sept. 14, 1910, and to confirm the action of the Executive Committee in ordering posted the names of all approved candidates.

Report was made of the questions which had arisen with the Post Office Department in the matter of securing second-class entry of The Journal.

Voted: To refer the matter back to the Publication Committee for further report.

Voted: To accept with thanks of the Council the progress report of the Research Committee and suggest that the matter be elaborated for presentation at the annual meeting.

Voted: To accept the report of the House Committee as presented by Mr. W. C. Dickerman, Chairman, and to express the thanks of the Council for their work during the past year.

The following vote of the Meetings Committee was read:

That the Council be requested to approve the appointment of a sub-committee of the Meetings Committee to consist of five members of the Society, to be known as the Committee on Economic Administration of Industrial Establishments, and to consist largely if not entirely of members holding administrative positions in such establishments. The duties of the Committee are to consist of the solicitation of papers on this subject, the judging of papers received, and their transmission, with their opinion, to the Meetings Committee; also to serve as a board of supervisors to the Meetings Committee on all questions relating to this subject.

Voted: To approve the appointment of a sub-committee of the Meetings Committee, and the committee be directed to proceed under the provisions of By-Law 23.

Voted: That the date set for the next monthly meeting of the Society, November 9, be also the date for a meeting of the Council.

Voted: To accept the progress report of the Research Committee and especially request that it be elaborated and with the valuable data obtained presented at the Annual Meeting Membership Committee.

Voted: On recommendation of the Membership Committee to approve the reinstatement of C. H. Hurd of Indianapolis, Ind., who resigned from membership in 1907.

Voted: To decline the application for Student Membership of the State University of Kentucky, Lexington, Ky.

Voted: To approve the application of Sheffield Scientific School, Yale, to form a student branch, to be known as Yale Mechanical Engineers' Club affiliated with The American Society of Mechanical Engineers.

Voted: To refer jointly to the Finance and Meetings committees consideration, with the Boston members, of the proposed plans for an engineering building in Boston and what part if any the Society can take.

Dr. Humphreys reported progress in the matter of the appointment of a Public Relations Committee.

Mr. Arthur M. Waitt, Chairman of the Finance Committee presented the following resolutions from his Committee which were approved:

That in view of the increase in the amount received from sales of publications from the estimate of $5000 to $9282, entailing an expense of $1401.28 above the appropriation, this amount to credited to the sales expenditure account from the excess of income for the year 1909–1910.

To cancel the balances of all other appropriations for 1909–1910 after reserving $4200 for the completion by the Publication Committee of Vol. 31 Transactions, all changes in appropriation being within the current income for the year.

To appropriate from current income for 1909–1910, $228.29 for the advances preliminary to the advertising of The Journal.

To transfer from current income to the Reserve Fund, $2400 to reimburse the Reserve Fund for all expenditures from that fund on account of the London Meeting during the fiscal year 1909–1910; and to approve the expenditure of $653.44 that has been made from current income on account of the London Meeting, thus providing the payment from the current income of this year of all expenses for the London Meeting incurred up to date.

That the action of the Council of October 24, 1906, relative to the disbursements from Land Fund, be rescinded now, so far as interest on the mortgage is concerned, and that in the future the interest on the Carnegie mortgage be included in the appropriations to be paid from current income.

To approve the budget as presented and to express the appreciation of the Council to the Finance Committee for the splendid financial showing for the year's work.

On motion meeting adjourned.

NECROLOGY

FREDERICK MERIAM WHEELER

Frederick Meriam Wheeler of Montclair, N. J., a charter member of the Society, died at his summer home in Westhampton, Long Island, on September 15, 1910.

Mr. Wheeler, who was born in Brooklyn, N. Y., in 1848, was graduated from Summit Academy in New Jersey, and subsequently attended the Polytechnic Institute, Brooklyn, N. Y. His early apprenticeship was served in the machine shop of the Lake Mills, Lake Village, N. Y., and he later studied mechanical engineering for five years under Henry J. Davison of New York City. He made hydraulic and marine engineering his specialty and for over thirty-four years was associated with the George F. Blake Manufacturing Company, of which he became director and secretary. When the company was absorbed by the International Steam Pump Company, together with other hydraulic works, Mr. Wheeler was made a director in the new company.

Mr. Wheeler was the inventor of the Wheeler surface condenser which is extensively used in this country and Europe and has been adopted by the United States Navy. He organized the Wheeler Condenser and Engineering Company, with works at Carteret, N. J., and was also officially connected with the Ludlow Valve Manufacturing Company.

In addition to his membership in the Society, Mr. Wheeler was a charter member of the Society of Naval Architects and Marine Engineers, and was also a member of the American Society of Naval Engineers and of the Engineers Club of New York. He served as a member of the advisory council of the Engineering Congress at the Columbian Exposition in 1892, and had for many years been prominent in public and social circles in his home city.

BARTON CRUIKSHANK

Dr. Barton Cruikshank, a member of the Society, was drowned in the St. Lawrence River on June 27, 1910, where he was conducting a boys' summer school and camp at Cedar Cliff, N. Y.

Dr. Cruikshank, who was born in Albany, N. Y., February 5, 1866, was educated in the public schools and Adelphi Academy of Brooklyn and in the Brooklyn Polytechnic Institute, where he received the degree of B. S.

After graduation he entered the shops of the Brady Manufacturing Company, in which he soon rose to be superintendent and assistant manager, finally becoming president. From there he went to Boston in the employ of the Boston Heating Company, and later to Princeton, N. J., as instructor in graphics and mathematics in the university. In 1891–1892 he acted as consulting engineer for the Indurated Fibre Pipe Company in New York, and in 1893 became superintendent of the Hammond Typewriter Company, Brooklyn. During his residence there, Dr. Cruikshank assisted Dr. Larkins in starting and organizing the first manual training high school in Brooklyn.

In 1899 he accepted the presidency of the Clarkson School of Technology at Potsdam, N. Y., from which he resigned in 1902 to become president of the Cogswell Polytechnic College in San Francisco. Two years later he returned to the East, entering the employ of the Solvay Process Company in Syracuse, N. Y., as designing engineer, where he remained until a year before his death when he took up the organization of his boys' camp, which was so unfortunately the scene of his sudden death.

CLAY BELSLEY

Clay Belsley, a member of the Society, died at his home in Peoria, Ill., on September 3, 1910. Mr. Belsley was born at Spring Bay, Ill., on January 28, 1873, and was graduated from Cornell University in 1898 with the degree of M.E. Soon afterward he entered the employ of the Link-Belt Company of Chicago, where he had charge of the mining machine plants. He later entered the service of the McEntee-Peterson Engineering Company of Peoria, by whom he was placed in sole charge of their work in the South, including the building of the electric light plant at Gastonia, N. C. In 1901, Mr. Belsley returned to Peoria and opened a private practice as consulting engineer.

Among other important work undertaken at this time, he designed an electric light and power plant for Tom J. Gardner at Las Animas, Colo., installed the mechanical and electrical plant of the Corning distillery, and had charge of the design and construction of all the work of the Woodruff Ice Company of Peoria. He was also engaged during this period in expert investigation in connection with legal work.

In 1908, Mr. Belsley accepted the appointment of City Engineer of his native city, resigning his lucrative private practice to perform this public service. While personally superintending the construction of a masonry culvert for the city, he contracted typhoid fever and from the resulting weakened condition never recovered.

ALFRED WILKINSON

Alfred Wilkinson, who died at his home in Bridgeport, Pa., on August 30, 1910, was born at Stockport, in Cheshire, England, May 17, 1845. Here he attended the common schools and the Mechanics Institute. When fourteen years of age he came to the United States, entering the Richmond shops of the Philadelphia and Reading Railroad Company where he remained till 1862. When the Civil War broke out he enlisted in the navy and served under Admiral Farragut, being promoted for meritorious service to third assistant engineer. At the close of the war he entered the employ of Carr, Crawley and Devlin, Philadelphia. In 1876 he opened an office of his own in Philadelphia as expert steam engineer, and in 1891 invented the automatic mechanical stoker which today bears his name and which is extensively used on ocean liners and in large manufacturing plants. In the same year Mr. Wilkinson organized the Wilkinson Manufacturing Company at Bridgeport, Pa., and began the manufacture of his invention. He was at the time of his death president of the company.

Besides being a member of this Society, Mr. Wilkinson was a member of the Franklin Institute and the Manufacturers' Club of Philadelphia. He inherited his mechanical genius from his father, Joseph Wilkinson, who invented a cook stove and an automatic oil cup for steam engines.

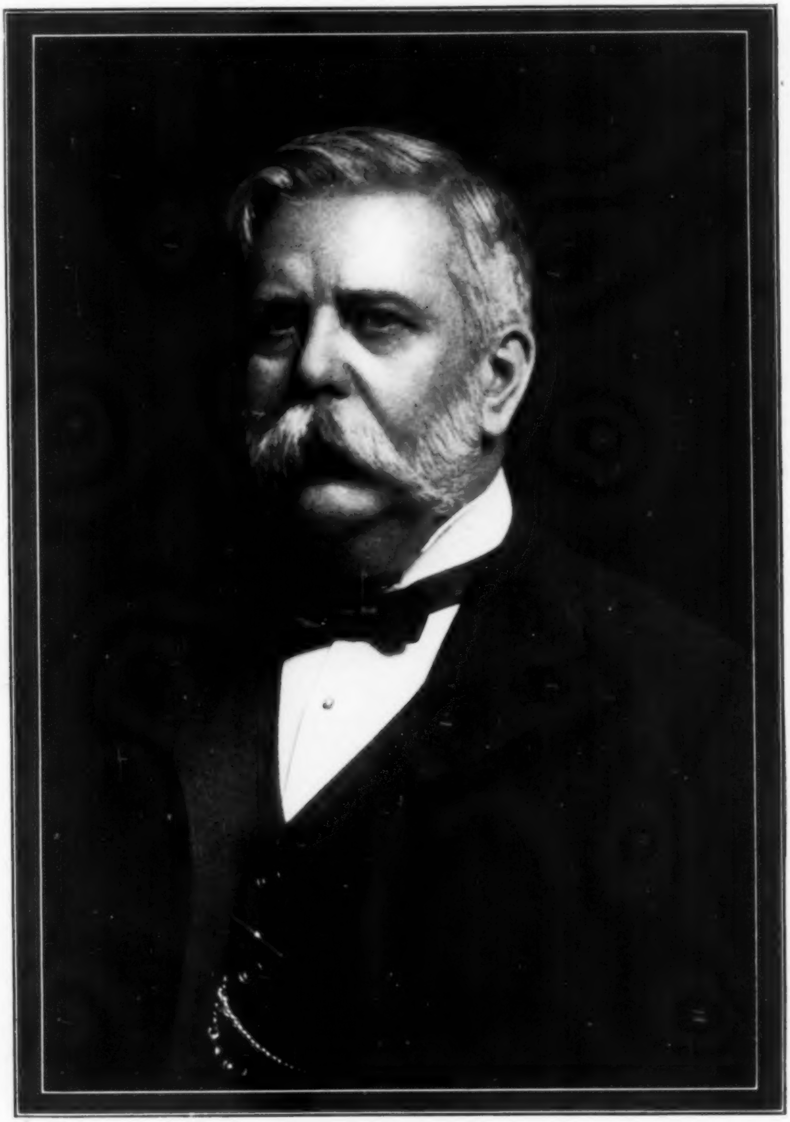
THE JOINT MEETING IN ENGLAND

ACCOUNT OF THE JOINT MEETING OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS WITH THE INSTITUTION OF MECHANICAL ENGINEERS

Birmingham and London, 1910

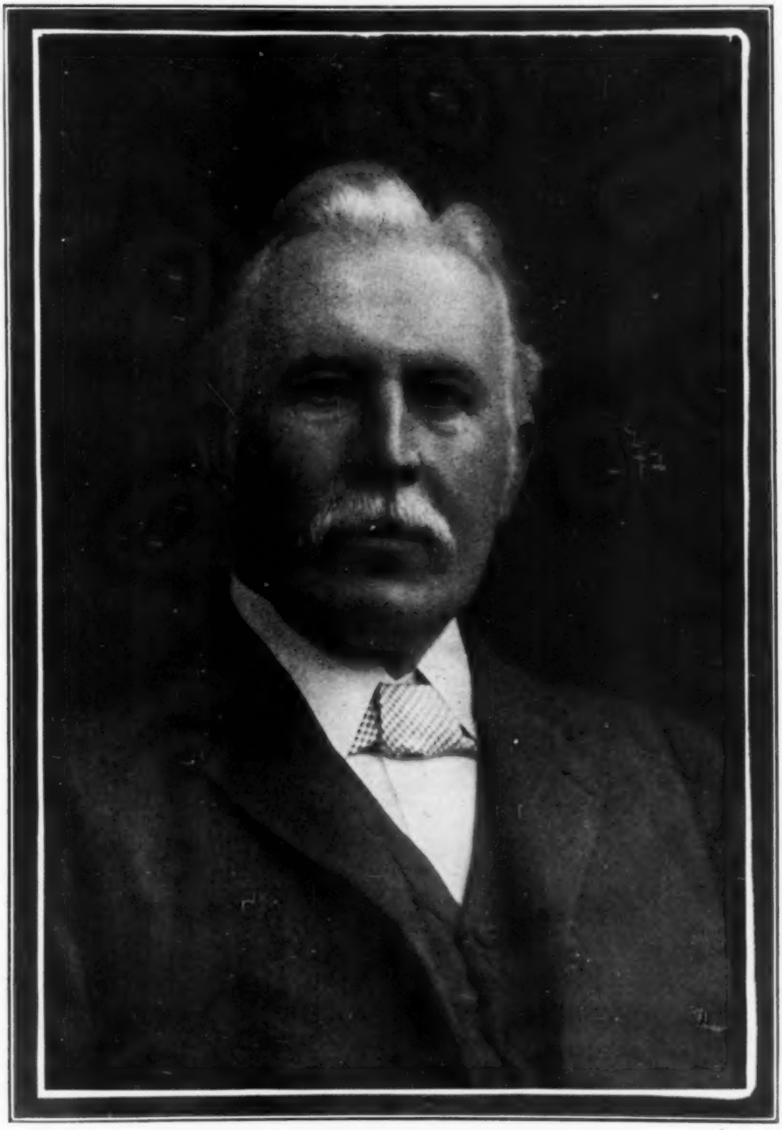
By Calvin W. Rice, Secretary

The American Society of Mechanical Engineers



GEORGE WESTINGHOUSE, PRESIDENT

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS



JOHN A. F. ASPINALL, PRESIDENT

THE INSTITUTION OF MECHANICAL ENGINEERS

THE JOINT MEETING IN ENGLAND

By Calvin W. Rice

TABLE OF CONTENTS

	Page
Officers and Council of the A.S.M.E.	1703
Committee of Arrangements	1704
Official Party	1705
Other Members and Guests in Attendance	1707
Officers and Council of the Institution	1708
Birmingham Reception Committee	1709
Members of the Institution in Attendance	1709
Invitation from the Institution and Acceptance	1712
Arrangements for Trip	1714
Events on Shipboard	1715
Welcome in Liverpool and Arrival in Birmingham	1721
Dinner given by President Aspinall	1723
Opening of the Joint Meeting:	
Welcoming Addresses	1724
Presentation of Watt Letter	1725
Papers on Locomotive Terminals	1726
Excursions and Trips	1726
Garden Fête	1730
Second Professional Session:	
Telegram from Mr. Westinghouse	1730
Papers on High-Speed Tools and Tooth Gearing	1731
Resolutions of Thanks	1731
Excursions and Trips	1732
Reception in the Council House	1733
Departure from Birmingham	1734
Excursions	1734
Conversazione in Institution House	1744
London Professional Session:	
Address of Welcome	1745
Papers on Electric Traction	1745
Resolutions of Thanks	1745
Garden Parties and Visits	1747
Institution Banquet	1747
Trips to Windsor and Marlow	1748
Dinner given by Sir Wm. H. and Lady White	1749
Service in Westminster Abbey	1749
Dinner given by Mr. Swasey	1750
Conclusion of Meeting	1750

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Griffiths, Harold, Birmingham
Guest, George Nevill, Birmingham
Harben, G. A., London
Harris, F. G. R., London
Harris, William Robert Alexander, Wooburn, Bucks
Hartness, John Anton, London
Hatton, James, Burton-on-Trent
Hayward, Joseph William, Montreal, Canada
Hibberd, Frederick Charles, Slough
Hicks, Frederick George, Birmingham
Hilton, N. L., Coventry

Hudson, Ernest Victor, Birmingham
Hurd, Milner, Dudley
Inkson, N. L., Jalampur, India
Jackson, Robert Hiram, Manchester
James-Carrington, Henry, Birmingham
Jewson, Herbert, Dereham
Johnson, Frederick Samuel Lovick, Sylhet, Assam, India
Ketley, Chas. Boswart, Birmingham
Lack, Charles Tibbit, Cambridge
Lake, C. S., London
Lane, Norman Augustus, Birmingham
Leach, Harry, London
Lewis, Paul Alexander, Wolverhampton
Lewis, W. Y., London
Lindop, William, Tipton
Lockwood, Bunce Y., London
Longhurst, Henry Alexander, London
Mackintosh, Donald Grant, Birmingham
March, S. H., Manchester
Marks, Alfred Pally, Birmingham
Maw, Henry, London
Maw, Robert Lewis, London
Maw, Thomas Frederick, London
McLaren, William David, Roorkee, N.W.P., India
Meaden, Albert Edward, Kuala Lumpor, Selangor, F.M.S.
Moody, George Henry, Bradley, Bilston
Morgan, D. H., Felstead, Essex
Nasmith, John, Birmingham
Nettlefold, Godfrey, Birmingham
Parker, John, Tipton
Parsonage, William Rawlett, Birmingham
Pinfield, William Vicary, Birmingham
Pochin, Edward Arnold, Manchester
Podesta, John James, Wolverhampton
Porter, Ralph Classon, Birmingham
Poulton, Wm., Sheffield
Pritchard, William Elias, Bangor
Pullin, Joseph Alexander, Birmingham
Radcliffe, John James, Rochdale
Redman, Sydney George, Newcastle-on-Tyne
Reynolds, Alfred Milward, Birmingham
Richey, William Frederick Albert, Birmingham
Robertson, Rudolph Alexander, Assam, India
Robey, Ernest William, Birmingham
Rosevere, Gerald Rhodes, Birmingham
Rosher, Noël Burn, Birmingham
Rushworth, David, Chesterfield
Scott, Woolby Lockwood, Ipswich
Scott-Linsley, Herbert Llewellyn, Worcester
Shapton, Norman William, London
Shepherd, James Horace, Wolverhampton
Smith, Dempster, Manchester
Smith, Louis William, Lincoln
Smith, Thomas John, Hanley, Staffordshire
Spencer, Henry Wilmot, London
Steven, James Dunlop, Birmingham
Suffield, Frank Wilson, Birmingham
Sunderland, Wallace, Leeds
Sutton, Frederick Bass, Birmingham
Swan, E. M., Cardiff
Symons, James Francis, London
Taylor, Charles Albert, London
Tomes, William Jameson, Jamalpur, Bengal
Utting, Samuel, London
Vickers, Ernest John, Birmingham
Wade, F. R., Birmingham
Wainwright, Walter Hepburn, London
Walker, Alfred, London
Walter, D'Arcy Joseph, Birmingham
Warner, Francis George, Birmingham
Watson, Herbert Edward, Calcutta
Whitehead Richard David, Derby
Whitehouse, George Henry, Tipton
Williams, John Robert, Sheffield
Williams, N. C., Birmingham
Williamson, Edward, London
Willis, Edward, London
Wright, Isaac Henry, Coventry

ASSOCIATES

Allen, William Edgar, Litt.D., Sheffield
Foster, George, Rotherham
James, Albert Alfred, West Bromwich
Kennan, Williams Thomas, Dublin

GRADUATES

Algar, S. C., London
Ansell, Arthur Molloy, Toong, Bengal
Aykroyd, John Kenneth, London
Baker, Edward, Rotherham
Bamford, J. I., London
Bentall, A. F., Chelmsford
Brander, James, Bristol
Brown, Ernest William, Leighton Buzzard
Bumpus, Frank Arnold, Loughborough
Carrick, Joseph Ernest Cecil, S. Milford, Yorks.
Currall, Edward Percy, Birmingham
Eid, Abd-el Fakah, Liverpool
Gledhill, Gilbert, Halifax
Guy, Henry Lewis, Penarth
Head, George Bruges Digby, London
Hillhouse, John Paton, Birmingham
Jordan, F. W., London
Kendall, Alfred Harold, Birmingham
Kingsmill, V. H., London
Lightfoot, Kenneth, London
Lloyd-Parton, Fred, Wolverhampton
Mann, Ernest Leonard, Lincoln
Maw, Arthur Ernest, Lincoln
Mercer, George Henry, Birmingham
Moss, F. C., Rotherham
O'Brien, George Holme, B.Sc., Manchester
Reeve, Edward, Birmingham
Shearman, John, Jun. London
Smith, Charles St. Vincent, Stoke-on-Trent
Somers, Frank, Birmingham
Symons, Angus Bryant, London
Vicars, Theo., Jun., London
Vining, Roy Veitch, London
Walker, Charles Albert, London
Wallbridge, C. S., London

THE JOINT MEETING, 1910

BY CALVIN W. RICE, SECRETARY

The American Society of Mechanical Engineers

In the Spring of the year 1909, Sir Robert Hadfield, a member of the Council of the Institution of Mechanical Engineers, brought to The American Society of Mechanical Engineers, on one of his frequent trips to America, the first intimation of a Joint Meeting to be held in England the summer of the following year. This was confirmed in September by the following formal invitation from our sister organization:

THE INSTITUTION OF MECHANICAL ENGINEERS

Storey's Gate, St. James Park, Westminster, S. W.

17th September, 1909.

Dear Mr. President:

At a Meeting of the Council of this Institution held today, the following Resolution was unanimously passed:

"That a very hearty invitation be sent to The American Society of Mechanical Engineers to participate in a Joint Meeting in England with the Institution of Mechanical Engineers, and that the Meeting be held in the Summer of 1910, if possible during the last week in July."

I need scarcely say how warmly the subject was supported by those present, especially as the Council had learnt from the Committee appointed to confer with Mr. H. deB. Parsons, the special representative of your Society, the cordiality with which the idea had been taken up by your Members.

We hope that we may be favored with the presence of yourself, your Council, and many of your Members at the proposed Meeting.

With all good wishes, we are,

Yours very truly,

JOHN A. F. ASPINALL
President

EDGAR WORTHINGTON
Secretary

The President
The American Society of Mechanical Engineers
29 West 39th Street, New York, U. S. A.

Former gatherings of a like nature had taught not only the value, but also the great pleasure to be derived from such a meeting of the two national mechanical engineering organizations, and by the unanimous vote of the Council of the Society the following reply was despatched:

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

29 West 39th Street, New York, U. S. A.

Dear Mr. President:

The Council of The American Society of Mechanical Engineers has considered the very cordial invitation of The Institution of Mechanical Engineers, to hold a joint meeting in England in the Summer of 1910, conveyed by your letter of September 17.

The Council was unanimous in the acceptance of the invitation and bids me convey to you its action as follows:

"Resolved,—That The American Society of Mechanical Engineers accept the very cordial invitation of The Institution of Mechanical Engineers, to hold a joint meeting in England in the Summer of 1910. The Council feels that the interests of Engineering throughout the World will assuredly be advanced by the giving and the acceptance of this invitation;—an evidence of an increasing coöperation among the various societies representing the Profession of Engineering."

In conveying this resolution of the Council permit us to inform you of the universal cordiality with which the invitation has been received both by the Council and by the Members of the Society. It is the expectation that a representative delegation of the Society will be present at the meeting.

Please accept our expressions of sincere good will.

JESSE M. SMITH
President
CALVIN W. RICE
Secretary

To The President
The Institution of Mechanical Engineers
London, England

The preliminary work of announcing this action to the membership was assigned to the Executive Committee of the Council as well as the tentative arrangements for transportation, whereby an option, expiring March 1, was secured upon the entire first cabin of the White Star Steamship Celtic, sailing July 16 for Liverpool.

The Committee of Arrangements immediately upon its appointment by the Council in the Spring of 1910 took up the task of perfecting these and other details, producing, under the able Chairmanship of Ambrose Swasey, Past-President Am.Soc.M.E., a result which made this meeting an event in the history of the Society.

NEW YORK TO BIRMINGHAM

The Celtic with the official party of 144 members and guests steamed from the White Star dock in the North River at two o'clock in the afternoon of July 16, under a cloudless sky, good augury of the voyage ahead. The Committee on Acquaintanceship which, with the characteristically energetic generalship of Dr. W. F. M. Goss, met immediately after dinner the same evening and remained continuously on duty until the end of the voyage, soon made the individual members of the party known to one another. Invitations, on which was embossed and colored the emblem of the Society, were also issued to the other members of the first cabin, cordially urging their participation in the events arranged for the week on shipboard, a thoughtful act suggested by Professor Hutton and Mr. Brill which was greatly appreciated. The entire group was thus at once brought into a friendly relationship not usually secured until the end of the journey.

The first day out, which was Sunday, was spent quietly in resting and visiting, religious services being conducted by the Right Reverend William D. Walker, Bishop of Western New York. On Monday, preliminary games were begun on deck. In the evening the officers and past-presidents of the Society, together with the officers of the Celtic, received the first cabin passengers on the upper promenade deck, thus bringing the party and the other voyagers into closer acquaintance. This is believed to be the first occasion in the history of the Celtic, if not of the steamship line, in which the officers of the ship participated in receiving the passengers. A dance followed the reception.

The lecture given on Tuesday evening by Worcester R. Warner, Past-President, on What are the Astronomers Doing, was not only entertaining but instructive, and was finely illustrated by lantern views, many of which were new and shown for the first time to any audience.

The musicale arranged for Wednesday evening proved one of the most enjoyable features of the trip, displaying to advantage the versatility of the Society's membership. The success of those in charge in enlisting the participation of the other passengers was exemplified in the acceptance of the chairmanship of the evening by Mr. Everett P. Wheeler, well-known in legal and political circles in New York City. The program follows:

SELECTION	Guglielmo Tell	Rossini
	Orchestra	
VOCAL SOLOS	*a* The Flower Song from Faust	Gounod
	b Ask Me no More	Tosti
	MISS GRACE BURLINGAME	
CELLO SOLOS	*a* Romance	Davidoff
	b Largo	Handel
	DR. LEONARD WALDO	
MONOLOGUE	The Village Dressmaker	Wiggin
	MRS. JESSE M. SMITH	
VOCAL SOLOS	*a* The Skipper of St. Ives	Roeckel
	b Three for Jack	Squire
	D. J. EDMONDS	
PIANO SOLO	Song Without Words	Mendelsohn
	MISS ALICE M. MAIN	
READING	The Limerick Tigers	Edwards
	PROF. F. R. HUTTON	
SELECTION	Three Dances Henry VIII	German
	Orchestra	

The appreciation felt by the first cabin passengers of the entertainments arranged by the Society was expressed by Mr. Wheeler at the conclusion of the musicale.

On Thursday evening, John R. Freeman, Past-President, gave an interesting illustrated address on the Construction of the Panama Canal, of which it is well known Mr. Freeman speaks with authority through his official connection with the Board of Engineers appointed by President Taft to visit the canal in 1909. Slides of a different character were afterward thrown on the screen, showing among other views a portrait of Captain Hambelton, and a reproduction of the menu card of the dinner given by Ambrose Swasey, then President of the Society, at the time of the last visit of the Institution to America in the year 1904. As the words of God Save the King were shown, the audience joined in singing the British national song. Friday evening was devoted to dancing.

A bridge-whist contest was held Thursday afternoon, and on Friday the sports took place, miscellaneous games being also in progress, during the entire week. Saturday evening had been set apart for the awarding of prizes to the winners of these various tests of skill and for a gathering of a more informal nature than those of preceding evenings. Prof. F. R. Hutton presided over the occasion, and after an orchestra had rendered a selection, Geo. M. Brill, Chairman of the Entertainment Committee, announced the following

awards: 1st prize in bridge-whist, to J. D. C. Darrell, a pair of flat brushes in a leather case; 2nd prize, to John Calder, a pigskin traveling case for collar buttons, etc.; 3rd prize, to Mrs. W. K. Carr, a hat pin; 4th prize, to Mrs. M. B. Orde, a bridge set; 1st prize in shuffleboard contest, to Karl Dodge, "Satchel Guide to Europe"; 2nd prize, to Theodore Main, "My Trip Abroad"; to the winner of the pillow fight, H. M. Klingenfeld, a knife on a small pillow; to the winner of the men's potato race, A. Wise, a coin purse; of the ladies' potato race, Miss H. E. Armstrong, a silver coin holder, and Miss Gertrude Baker, a silver pencil; and to the winner of the obstacle race, Karl Dodge, a coin purse. A so-called endurance prize, a fan, was also given to Mrs. Jesse M. Smith, the last lady to stay in the game of shuffleboard. A consolation prize, consisting of a doll, was contributed by friends to Frank B. Gilbreth, who lost in the final round of shuffleboard, and also as a mark of appreciation of his efficient service as Chief of Police in maintaining order during the games. Prof. F. R. Hutton received a loving cup, of the telescopic variety. As each winner came forward to receive his or her prize, a speech was demanded, thus eliciting a number of impromptu remarks which greatly added to the merriment of the evening. Most of these prizes, chosen with characteristic good taste, had been appropriately engraved or stamped with the name of the Society and the occasion, through the thoughtfulness of Mr. and Mrs. Brill.

James M. Dodge, Past-President, followed with a humorous lecture, entitled An Exhaustive Review of the Formation of the Earth and its Oceans, with Some Conclusive Educational Remarks on the Solar System and Prognostications on the Ultimate End of the Universe, in which he assumed to controvert the theories of all other scientists. A jury consisting of Ambrose Swasey, John R. Freeman, William H. Wiley, Oberlin Smith, Jesse M. Smith, George M. Brill, Calvin W. Rice, H. L. Gantt, Prof. W. F. M. Goss, Prof. Arthur M. Greene, Jr., James Hartness and F. H. Stillman, had been chosen to sit in judgment on his arguments and, clad in the robes of office, filed in with due solemnity as Mr. Dodge began his address. Mrs. E. B. Danforth, eighty years of age, then rendered a piano solo, and A. T. Baldwin read the following "Engineer's Reverie," written by Granger Whitney, Superintendent of the Detroit Iron and Steel Company, a member of the Detroit Engineering Society:

WHAT'S THE USE

By Granger Whitney, Detroit, Mich.

What's the use of running levels on a hillside that is steep?
What's the use of building railroads through the valleys that are deep?
With your cantilever bridges, with record breaking spans,
Your aids to navigation, your ship locks and your dams.
Oh, the hydrostatic pressure at the Sault, it gives me chills,
And the dusty, smoking tunnel running through the Hoosac hills
Makes me weary with existence; the canal at Panama
Seems a labor of utility thats hardly up to par.
Oh—What's the use?

What's the use of doubling up your work on multiple machines
Till the weary brain is pinioned to a rack of grasping schemes?
Your indicator card will show expansion of the head,
Exhaustion of the intellect, the cut-off finds you dead.
With monoplane and gasolene you navigate the air,
Your differential valve gear drives a man to deep despair,
With many new inventions you strive till you obtain
The ecstatic culmination of an epicylic train.
Oh—What's the use?

What's the use of sinking shafts six thousand feet at Calumet?
What's the use of stoping out the Colorado sulphurets?
Now it's conical drum engines and ventilating fans,
Then the cyaniding process and amalgamating pans,
Steam shovels do your digging in a most efficient way,
Six hundred tons of Bessemer you're smelting in a day.
It's economy and saving with gas seal and double bell,
Eighty-five percent Mesabe and your tops blown all to hell.
Oh—What's the use?

What's the use of putting bilge keels on an ocean going ship,
Let her roll and let the lubbers seek their bunks or miss the trip.
There's forced draft on your boilers, you have sixty feet of beam,
You move with two propellers and a trinity of steam.
With twelve-foot center hatches and twelve thousand tons below
How your rivets groan and tremble when the wind comes on to blow.
Three days from Escanaba to Conneaut, your goal,
And there you fuss and fidget till you're sailing north with coal.
Oh—What's the use?

If you're going to be a pessimist there isn't any use
Of building ships or mining ore or generating juice.
If your ultimate ambition is to roll a ton of rails,
To build an automobile or to make a keg of nails
You will find that life's a burden, you will find existence stale,

If you live by rule and precedent you pretty sure will fail,
And if you only work and sleep and take three meals a day
Why there isn't any answer and it really doesn't pay.
So—What's the use?

It's the friends you've got in Denver, it's your life out on the hills,
It's the men you met at Panama, your record with the drills,
It's the girls you've met on ship board at Harrisburg, the friends you left at home,
It's that plutocratic feeling when you're hiking down from Nome.
It's the people up in Scranton, it's the folks you met in Lynn,
It's your cronies out in Pueblo, it's the places you have been,
It's the life you led at Phoenix when you crossed the great divide,
It's the work you did at Jarrow, it's your record on the Clyde.

It's the golf you played at Birmingham, your San Francisco spree,
It's when you saw the springtime clothe the hills of Tennessee,
It's the drinks you drank in Pittsburg in your youthful days of joy,
It's that forty mile excursion from Schenectady to Troy,
It's the days you spent in Helena, your luck at Cripple Creek,
It's the gang at South Chicago that never went to sleep,
It's the fellows at Altoona, it's the men that sing and laugh,
It's the men you've known and lived with from Newport News to Bath.

It's when the day is over and your work is all well done,
It's when the campaign's ended, it's when the battle's won,
Then friendship keen, and memory of many happy days
Bring the glorious satisfaction that a life of action pays.
That's the use—That's the use—
And we'll drink a toast to energy and raise a merry song,
We'll lead a life that's strenuous, we'll work a day that's long.
And when that day is ended and our work is damned well done
We'll meet around the festal board, we'll have a little fun.
That's the use.

Ambrose Swasey, Chairman of the Committee of Arrangements, expressed briefly the Society's appreciation of the courtesy and friendliness of the ship's officers, which had added so much to the week's voyage, and as a memento of the trip presented to Captain Hambelton a silver case, beautifully chased and engraved with the words, PRESENTED TO CAPTAIN A. E. S. HAMBELTON, COMMANDING S. S. CELTIC, BY MEMBERS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, JULY 23, 1910; and to Chief Engineer Lapsley an electric desk lamp, with Tiffany favrile glass shade, similarly engraved. These tokens came as a great surprise to their recipients, who expressed their thanks in a few graceful remarks.

Professor Hutton brought the program to a close with the following poem written by him for the occasion:

AN - ODE; WITH KATH - ODE

By F. R. Hutton, New York

Honorary Secretary of the Society

THE AN—ODE

There once was a "Gang" transatlantic
Up to all sorts of lark and of antic;
    The Celtic's so steady
    That each one is ready
For play, spite of sea rough and frantic.

They have heard about comet and star,
In dancing, they've scampered afar,
    At the "Tigers" they've smiled,
    Been by "Bell-buoy" beguiled,
And learned, too, about Panama.

We have Swasey to act as our Boss,
We have chuckled with Hartness and Goss,
    And with Miller, (T. Spencer),
    As stunt-scheme dispenser
The trip's end seems much like a loss.

One lad used a big megaphone;
Perched aloft, with a loud brassy tone,
    He told us who scored
    When they played shuffle-board
With a glee which is just Dodge's own.

One uses a lot of his breath
We all like to hear what he saith:
    His nonsense is fine
    I wish like it for mine
But can he be "wasting," Gilbreth?

Nor must we forget our police
So great in preserving the peace;
    Were "face-making" a crime,
    Then "gum-chewing's" sublime,
And grave misdemeanours must cease.

THE KATH—ODE

We seem to be nearing the shore
When our larks for a while will be o'er
But we'll never forget;
And the friends we have met
Will be mem'ries of joy ever more.

So here on our last festal night
And with Ireland almost in sight,
We sing "Hail to the Chief"!
(To Lapsley, in brief)
Who has handled our engines' great might.

But to Hambelton—bless heart and head—
Our last friendly word shall be said:
"Good luck" and "Good-bye,"
We unite in the cry:
From the sea he has lifted all dread.

After singing My Country 'tis of Thee, appropriately followed by God Save the King, the company dispersed amid many expressions of appreciation. During the evening a collection was taken for the Seamen's Charities of Liverpool and London.

The program of Saturday evening, which was characterized throughout by a spirit of goodfellowship, brought to a close the unique and delightful series of events provided by the Committee on Entertainment, to whom as well as to the general committee so much of the pleasure of the trip was due. Indeed too much praise for the perfection of the entire series of entertainments cannot be accorded the Chairman and his committee, who not only followed out various suggestions made by the membership, but so elaborated them as to make the best possible provision for the pleasure of the voyagers. The friendships formed on such a journey, which must remain a source of satisfaction long after the details of the trip are forgotten, and which contribute so much to the welding together of the Society's membership, were, it is needless to say, a feature the importance of which cannot be measured. The greatest regret was expressed on every side at the unavoidable absence of President and Mrs. George Westinghouse. The entire trip was remarkable for fine weather and smoothness and was made comfortable and pleasurable to all by the excellent service.

At six o'clock Sunday evening, July 24, the Celtic entered the River Mersey, where she was met by the White Star tender Magnetic,

bringing a deputation from the Lord Mayor of Liverpool and from the Institution of Mechanical Engineers. The party consisted of Deputy Lord Mayor, Henry Lea, Esq., a member of the Council of the Institution and formerly Lord Mayor of Liverpool; J. A. F. Aspinall, President of the Institution; Prof. W. H. Watkinson of Liverpool University, a member of the Institution; Edgar Worthington, Secretary of the Institution; and several others, all of whom brought to the American Society the official greetings of the city of Liverpool and of the British organization. In the absence of President Westinghouse, Vice-President Goss and other officers of the Society received the guests in the saloon of the Celtic. The Deputy Lord Mayor in a cordial speech regretted the unavoidable absence of the Lord Mayor of Liverpool, on whose behalf he bade them welcome as brethren both in blood relationship and in professional interests. America, he had found in his own visits to that country, a delightful place inhabited by delightful people, and he hoped that England might prove both enjoyable and profitable to the visitors.

Mr. Aspinall then tendered the welcome of the English Institution, which had so long been anticipating the visit of its American brothers. Great Britain, he said, was a somewhat acquisitive nation and it was hoped that the visitors would leave behind them a great volume of good mechanical ideas, and that they would find the visits to British works of as great interest and value as he had found those which he had made in America. In the United States, he understood, university work for engineers was ahead of that in Great Britain, and the graduates from these colleges were so numerous and energetic that they were spreading themselves over the British colonies.

Professor Watkinson followed with a few remarks regarding American colleges, describing his recent visit and the kindly treatment he had received, and expressing himself as deeply impressed by the magnificent equipment and the enormous research work being done. He concluded with a cordial welcome from the engineering department of Liverpool University.

Edgar Worthington, a friend of long standing of the American Society, was also called upon for a few remarks. Mr. Fothergill, representing the management of the White Star Line, made a short speech placing the facilities of his company at the disposal of the travelers upon arrival.

These hearty greetings were acknowledged by Vice-President Goss, who expressed the gratification of himself and of his American friends, and their keen appreciation of the coming events.

After the welcoming delegation had departed, the Celtic was towed to her dock to remain over night, the party landing in Liverpool the next morning and, after the necessary formalities of the customs, proceeding at once to the Lime Street Station where special dining coaches waited to convey them to Birmingham. President Aspinall of the English society, together with Mrs. Aspinall and their daughters, and also Fred. W. Taylor, Past-President of the Society, and Mrs. Taylor who had reached England some days earlier, were on board the train to greet the party.

At Birmingham, Messrs. Howard Heaton and Fred. M. Lea, Honorary Secretaries of the Local Committee, received the party upon their arrival and escorted them to motor omnibuses which conveyed them to their respective hotels. So thoroughly had the Committee on Transportation, Charles Whiting Baker and the Secretary, done its work that not only had hotel accommodations for each individual been arranged in Birmingham and London, but no one from the time of the departure of the Celtic to the close of the meeting in London, was obliged to concern himself in the least regarding the disposal of baggage.

On Monday evening President Aspinall tendered a dinner at the Queen's Hotel to the Past-Presidents and Council of the American Society, to which were also invited the Council and Past-Presidents of the Institution. The Lord Mayor of Birmingham, Alderman W. H. Bowater, was the guest of honor. There were also present, Dean W. F. M. Goss, Sir William H. White, Sir Oliver J. Lodge, Charles Whiting Baker, Arthur Keen, Ambrose Swasey, Sir Gerard A. Muntz, Bart., James Mapes Dodge, William H. Maw, Jesse M. Smith, Sir George Kenrick, Oberlin Smith, Edward P. Martin, Prof. F. R. Hutton, J. Hartley Wicksteed, Prof. R. C. Carpenter, Joseph S. Taylor, Walter Pitt, J. C. Vaudrey, Henry Lea, Henry L. Gantt, H. A. Ivatt, Robert Matthews, H. Graham Harris, Worcester R. Warner, H. F. Donaldson, William H. Allen, Howard Heaton, Alderman Sir Hallewell Rogers, John R. Freeman, Prof. W. Cawthorne Unwin, Arthur T. Keen, Edgar Worthington, James Hartness, Hon. William H. Wiley, Loughnan Pendred, Mark H. Robinson, Fred. M. Lee, E. B. Ellington, Frederick W. Taylor, F. Dudley Docker, George M. Brill, Michael Longridge, George Tangye, Edward Hopinkson, George Robert Jebb, Capt. H. Riall Sankey Reginald K. Morcom, Godfrey Nettlefold, Dr. H. S. Hele-Shaw, Eric M. Carter, and the Secretary. Toasts were given to the King, the President of the United States, and to the Guests. Respecting the latter, Mr. Aspinall spoke of his gratifi-

cation at the welcome which the city of Birmingham had accorded to the American visitors and of the great regret felt by all at the absence of Mr. Westinghouse, to whose coming all had looked forward, some in appreciation of him as a friend and a splendid host, and all in admiration of him as an engineer known from one end of the world to another. It was most appropriate that the societies should gather in Birmingham where the Institution of Mechanical Engineers was founded in 1847, under the leadership of its first president, George Stephenson, in a hotel of the same name, if not the very building in which this dinner was now held. Referring to the Joint Meeting now in progress, it had for an object, he said, not only the study of the work of our brother engineers, but the widening of acquaintance with one another.

Dr. Goss, as acting President, responded to this toast on behalf of the Society, and brief remarks were also made by Ambrose Swasey and other members.

TUESDAY, JULY 26

The Joint Meeting was formally opened on Tuesday, July 26, at 10 o'clock, in the Lecture Hall of the Birmingham and Midland Institute. The officers of the two societies who had assembled in the Institute Board Room previous to the meeting, entered the hall in a body at the beginning of the session, and took their assigned seats on the platform. The American Society was represented by Dr. W. F. M. Goss, James M. Dodge, John R. Freeman, F. R. Hutton, Jesse M. Smith, Oberlin Smith, Ambrose Swasey, F. W. Taylor, Worcester R. Warner, Charles Whiting Baker, E. D. Meier, Henry L. Gantt, James Hartness, Wm. H. Wiley, Willis E. Hall, and the Secretary. The Lord Mayor of Birmingham, Alderman W. H. Bowater, heartily welcomed the members to the city on behalf of the Reception Committee, whose chairman, Mr. Neville Chamberlain, was prevented by a slight accident from being present, and expressed the hope that the American visitors would feel when the time came for their departure that they had been treated not as strangers but as members of the same brotherhood. It was very fitting that Birmingham, the birthplace of the English Institution, considered the very center of mechanical engineering, should have been selected for so important a gathering as the present meeting. Some people did not think it a very beautiful city, but its own inhabitants were delighted with the darkness of the atmosphere and the ever-present smoke because the more plentiful the smoke the greater the volume of business in the workshop.

The Lord Mayor was followed by Mr. George Tangye, Vice-Chairman of the Reception Committee, who as custodian of the Boulton and Watt relics, offered to the Society a framed letter written by James Watt in 1777, as a memento of their visit to Birmingham. President Aspinall of the Institution in expressing his own appreciation of this gift by Mr. Tangye to the American Society referred to the close connection between the two nations as illustrated by the fact that Boulton and Watt sold to Robert Fulton his first engine. Birmingham had thus played its part in engineering work on both sides of the Atlantic. Another of its citizens, James Wyatt, invented the first cotton-spinning machine in 1741 and the first hanks of cotton produced by it might be viewed at any time in the city museum. Engineers recognized, he said, how much they owed to Birmingham and how much the city had done and was doing, not only in scientific advancement by means of their great university, but by the hard-headed constructive knowledge and ability of the people who fought to keep in British hands by the peaceful weapons of commercial conquest a fair share of the world's trade.

Dr. W. F. M. Goss expressed the hearty thanks of the American Society for the welcome accorded them and to Mr. George Tangye for his generous gift. This was the third official visit of the Society to England and previous experience had taught the members how great a privilege it was to be the guests of the Institution. Entering England with a recognition of how many practices of the profession had their beginning here, they were already in full enjoyment of everything found in the country, from the green of the trees and meadows to the permanency and beauty which characterized so many of the engineering structures. Under present-day conditions the engineer had become the world's great civilizer and in the transforming process in which men had been given new occupations and the world of their fathers replaced by a new world, the engineers of England and America had had a large part. National boundaries no longer affected them for, thanks to the English shipbuilders, the ocean between them had become an easy means of communication. The spirit of the two organizations, if not the organizations themselves, might be federated, and to such a result this Joint Meeting was sure to prove a contributing factor. Mr. Tangye's generous gift had quite taken them by surprise and they would not forget the giver in their enjoyment of the new possession.

The inscription on the frame of the memorial was then read:

PRESENTED TO THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS BY GEORGE TANGYE AT THE JOINT SUMMER MEETING AT BIRMINGHAM IN JULY, 1910. Dr. Goss added that the letter was both written and signed by James Watt, and was very legible and well preserved in every respect. A photograph of the letter, showing the two sides, is given herewith.

Mr. Aspinall then took the chair and at his request a telegram of regret was sent to Mr. Westinghouse.

After the transaction of some routine business the following papers were read and jointly discussed, the chair being alternately occupied by Mr. Aspinall and Dr. Goss on this and succeeding days: English Running-Shed Practice, by Cecil W. Paget, Member I. Mech.E., General Superintendent, Midland Railway, Derby; Handling Locomotives at Terminals, Frederic M. Whyte, Vice-President Am.Soc.M.E., General Mechanical Engineer, New York Central Lines, New York; Engine-House Practice, F. H. Clark, Mem.Am.Soc.M.E., Chicago, Ill.; American Locomotive Terminals, William Forsyth, Mem.Am. Soc.M.E., Railway Age Gazette, Chicago, Ill.; and Handling Engines, by H. H. Vaughan, Member I. Mech.E. and Am.Soc.M.E., Canadian Pacific Railway, Montreal, Can. The discussers were George Hughes, James M. Dodge, Henry Fowler, Henry L. Gantt, Arthur D. Jones, J. E. Sague, F. H. Clark, Cecil W. Paget, William Forsyth, F. M. Whyte and H. H. Vaughan.

Tuesday Afternoon and Evening

After luncheon, which through the courtesy of the Lord Mayor, was served in the Town Hall, the visitors scattered to enjoy the various trips to places of professional and historical interest in and about Birmingham, arranged by the local Reception Committee for both Tuesday and Wednesday afternoons. One of these was a trip to Dudley Port, Tipton, where inspection was made of the works of the South Staffordshire Mond Gas Company, under the guidance of the Managing Director, Edmund Howe, Esq., Member I.Mech.E. This company distributes gas for power and heating purposes over an area of about 123 sq. mi., in what may be termed the industrial heart of England. The plant comprises eight producers, each capable of gasifying 20 tons of fuel per day and generating sufficient gas to drive gas-engines of 2000 h.p. continuously. Here also the testing station of the Pump and Power Company was visited, which contains four Humphrey pumps of various types, the largest of which is 4-

cycle, delivering 250,000 gal. per hr. to a height of 35 ft. H. A. Humphrey, Esq., Managing Director, Member I. Mech.E., conducted the party.

Another excursion was that made to the works of the Austin Motor Company at Northfield, under the guidance of H. Austin, Esq., Governing Director, where the range of models manufactured comprises the 4-cylinder engine of the 25 to 30 h.p. type; a smaller model of 18 to 24 h.p.; a 15-h.p. 4-cylinder model in two forms, one having the engine in front and with narrowed frame used for taxicab work, and the other the engine under the driver's seat, used for landaulet or coupé carriages, or light delivery vans to carry loads up to 15 cwt.; a 7-h.p. single-cylinder; a 50-h.p. 6-cylinder; and an 18 to 24-h.p. 4-cylinder of a special type fitted with detachable wire wheels. The works of the company occupy over six acres, one building being devoted to the machine shops, and the other departments being the grinding section, hardening shop, power house, engine test-house, plating and polishing sections, erecting shop, copper and tinsmith's shop, chassis test-house, wheel building shop, finishing shop, patternmaker's shop, carriage building shop. The restaurant of the company, where the guests had tea, is shown herewith.

A third party, conducted by the Managing Director, Percy Wheeler, Esq., Member I.Mech.E., visited the Metropolitan Amalgamated Railway Carriage and Wagon Company at Saltley, which covers 20 acres and comprises a smith, smithy power house, steel under-frame shop, machine shop, power house, boiler house, foundry, saw mill, gantry, wagon building shop, car body shop and paint shop. These works are lighted by electricity generated on the grounds and employ about 3000 men.

The Frankley Filter Beds to which a trip was also arranged, are situated near Northfield, and form a portion of the Elan Supply Works designed to furnish eventually 72,000,000 gal. per day. Points of especial interest are the reservoir, filter washing, pure water reservoirs, pumping station, and the mains and meters. The resident engineer, F. N. Macaulay, Esq., acted as escort. On all of these trips tea was served at the works, usually in the employees' mess room, commonly found in English workshops.

An excursion to Stratford-upon-Avon included visits to Shakespeare's birthplace, the Church, the Memorial Theatre, Anne Hathaway's Cottage, and other points of interest. Tea was served at the Shakespeare Hotel. Many of our party were interested in the fact that The Piper, a play written by one of our own country-

women, the wife of one of our members, Josephine Preston Peabody (Mrs. L. S. Marks), of Cambridge, was to be produced for the first time on Wednesday evening at the Memorial Theatre, having been awarded the £300 prize in a world's contest. A number of the members of the Society were present at this initial performance which received much favorable criticism.

A trip was also made to the historic town of Worcester, "The Faithful City," where at the Guildhall the Mayor, Hon. Alfred Percy Allsopp, and the Corporation of Worcester, welcomed the party. At the Cathedral, on the eastern bank of the Severn, the Dean, the Very Reverend Dr. W. Moore Ede, gave a brief historical address, tracing the growth of the group of buildings from their beginning as a small Benedictine Monastery in 680 A.D., through the building period fostered by the Normans in the eleventh century, their vicissitudes under Henry VIII and again under Cromwell, to their final restoration in 1874. This great cathedral of the Western Midlands is simple in plan, and while the restoration has of necessity removed much of the "atmosphere" of antiquity so dear to the American visitor, the interior has a wonderful perfection of design, and gives proof of the most reverent care.

The party also visited the Worcester Porcelain Works which were founded in 1751 by Dr. John Wall, a distinguished physician and artist who succeeded in producing one of the most beautiful of the porcelains and to whom in 1788 King George III granted a patent which gave to Worcester the first royal porcelain works in England; as well as the quaint Hospital of St. Wulstan, commonly called the Commandery, which dates back to the 11th century. The entire place is rich in historical associations, intimately connected with the Civil War, and is full of carvings, furniture and objects of art.

Some of the party also visited Stoneleigh Park where after a view of the ruins of the old Cistercian Abbey built in the 16th century the party proceeded to Kenilworth, seeing the Castle and having tea at the Abbey or Kings Arms Hotels.

All of these trips were arranged by the Committee with the greatest care and forethought for the welfare and pleasure of the visitors, special trains or motor buses as well as guides being supplied in every case, and provision being made for both luncheon and tea. On the technical excursions these were furnished through the courtesy of the companies.

Birmingham itself contains so many places of professional interest that many of the guests took advantage of the opportunity to inspect

some of the engineering works located in the city, among the most prominent of which are James Archdale and Co., Manchester Works; Aston Manor Corporation Electric Power Station; Birmingham Corporation Electric Supply Station; James Cartland and Son; Elkington and Co.; General Electrical Co., Witton Works; Joseph Gillott and Sons, Metallic Pen Manufactory; National Telephone Co.'s Exchanges; F. and C. Osler; Taylor and Challen, Derwent Works; H. W. Ward and Co.; Webley and Scott; E. G. Wrigley and Co., Foundry Lane Works.

The older part of the city is crowded with these workshops and warehouses, but the modern part is well built and full of fine specimens of architecture. Most of its municipal undertakings date back to 1875 when Mr. Joseph Chamberlain, then its Mayor, inaugurated the new era.

A Ladies' Committee, consisting of the Lady Mayoress, Mrs. W. H. Bowater, Chairman, Mrs. Horatio Lane, Honorary Secretary, and Mesdames C. G. Beale, George Beech, Eric M. Carter, James Chatwin, George Vonaty, A. E. Cutler, David Davis, H. Ashton Hill, E. C. Keay, E. Antony Lees, Sheffield, J. D. Steven, William Tangye, J. C. Vaudrey and Miss Vaudrey, W. E. Warden, and Philip J. Worsley, on Tuesday and Wednesday mornings escorted the visiting ladies to various points of interest in the locality, providing special omnibuses for the trip.

Many of the members also accepted Mr. George Tangye's kind invitation to visit the Watt room in Heathfield Hall which, formerly the home of James Watt, has been occupied by Mr. Tangye for the past 25 years. The room is in every detail of its contents just as Watt left it, and all who appreciated the splendid genius of this early engineer could not but view with reverence the hundred-year-old stove, containing the ashes of the last fire burnt in it while Watt lived; the chest of drawers full of odd bits of metal, scraps of wood, mathematical instruments and the like; the first copying press, one of Watt's inventions, now standing with the dust of years upon it; his lathe with its lamp and tools untouched and the leather apron hung up where he left it; and many perfected or half-perfected processes or machines, all showing so clearly his instinct and passion for invention. The curator of these relics, which Mr. Tangye long ago presented to the city of Birmingham, made the visit doubly interesting by his personal guidance and explanation. A copy of the portrait of James Watt, painted by Sir William Beechy, which hangs in the dining room at Heathfield, is here reproduced through the kindness of Mr. Tangye.

The brilliant garden fête given by the Birmingham Reception Committee on Tuesday evening in the Botanical Gardens at Edgbaston, and attended by more than 5000 guests, was remarkable for the lavishness of its hospitality as well as for the splendor of the entertainment afforded and the scenic effect produced in the grounds. On every hand strings of miniature lamps and Japanese lanterns cast a radiant glow upon the paths and the awnings of the conservatories and lawn. The Lord Mayor and Lady Mayoress, Alderman and Mrs. Bowater, Alderman Sir G. H. Kenrick, Sir Oliver J. Lodge, Mr. Henry Lea and Mr. George Tangye, received the members and friends in the Floral Hall which was especially decorated for the occasion. Music was furnished by the band of the Royal Marines of Portsmouth and during the evening a series of fine fireworks was displayed, including a set piece showing the British and American flags crossed in the air. An elaborate luncheon was served in the tents and the American guests were conveyed to and from their hotels by special motor omnibuses.

WEDNESDAY, JULY 27

The meetings in the Midland Institute were resumed on Wednesday morning at 10 o'clock, when the following cablegram was read from President Westinghouse in reply to that of Mr. Aspinall sent on Tuesday: "Express my deep appreciation to Lord Mayor, Aspinall, Goss and Members both associations for their expressions of regret because of my absence and for their good wishes. I have the highest hope that the Joint Meeting will be of permanent value in further cementing the relations between the societies, and in promoting coöperation between the engineers of the two countries."

The following papers were then presented and discussed: High-Speed Tools and Machines to Fit Them, by H. I. Brackenbury, Member I.Mech.E., Elswick Works, Sir W. G. Armstrong, Whitworth & Co., Newcastle-on-Tyne; Rapid Production in Machine Work; Abstract of Data Collected by The American Society of Mechanical Engineers, read by John Calder, Mem.Am.Soc.M.E., Manager, Remington Typewriter Works, Ilion, N. Y.; Data on Manufacturing Methods with Machine Tools, by Luther D. Burlingame, Mem.Am.Soc.M.E., Chief Draftsman, Brown & Sharpe Co., Providence, R. I.; and Development of High-Speed Drilling Machines, by L. P. Alford, Mem.Am.Soc.M.E., Engineering Editor American Machinist, New York. They were discussed by J. Hartley

Wicksteed, William Lodge, Dempster Smith, Frank B. Gilbreth, H. I. Brackenbury, Daniel Adamson, George Addy, Alexander Taylor, W. F. M. Goss and John A. F. Aspinall.

Papers on Tooth Gearing, by J. D. Steven, Associate Member I. Mech.E., Messrs. E. G. Wrigley & Co., Soho, Birmingham; and on Interchangeable Involute Gearing, by Wilfred Lewis, Mem.Am.Soc. M.E., President Tabor Manufacturing Company, Philadelphia, and Chairman of the Committee on Standards for Involute Gears, were also read in abstract, and were discussed by P. V. Vernon, C. R. Gabriel, Luther D. Burlingame, Daniel Adamson, Thomas Humpage, R. M. Neilson, J. R. Williams, and Wilfred Lewis.

President Aspinall moved that the following resolutions of thanks to their hosts and to the many people in and around Birmingham for the great hospitality which they had extended to the members of the two organizations be accepted:

That the best thanks of the Members of the Institution of Mechanical Engineers and The American Society of Mechanical Engineers in this meeting assembled be given:

To the Right Hon. the Lord Mayor of Birmingham, Alderman W. H. Bowater, for his welcome of the President, Council, and Members of the two institutions to the city of Birmingham; for his and the Lady Mayoress's kind invitation to a Reception in the Council House; also for his courteously lending the Town Hall for the purposes of the luncheons.

To the Ladies' Committee for so kindly entertaining the lady visitors.

To the Chairman of the Reception Committee, the Lord Mayor; the Vice-Chairmen, Alderman Sir George H. Kenrick, Mr. Henry Lea, Sir Oliver J. Lodge, D.Sc., Ll. D., F.R.S., Mr. George Tangye; the Hon. Treasurer, Mr. Alexander Fyshe; and the members of the Birmingham Reception Committee, for the attractive programme they have prepared for the meeting and excursions, and for their hospitable entertainment of the members at the garden fête.

To the Chairman and Directors of the South Staffordshire Mond Gas (Power and Heating Co.), the Pump and Power Co., the Austin Motor Co., the Metropolitan Amalgamated Railway Carriage and Wagon Co., Mr. F. W. Macaulay, Messrs. E. G. Wrigley and Co., Messrs. Mitchells and Butlers, Messrs. Walter Somers and Co., and the numerous proprietors of places of engineering interest in Birmingham, Coventry, Rugby, and neighbourhood, for their kindness in throwing open their Works for the visits of members and for hospitalities; also to the Birmingham and Midland Institute, the Birmingham Association of Mechanical Engineers, and various clubs and the Birmingham Exchange for the extension of hospitable facilities.

To the Right Hon. the Earl of Warwick for inviting the members and ladies to visit Warwick Castle.

To the Right Hon. the Earl of Clarendon for permitting the members and ladies to visit Kenilworth Castle.

To the Right Hon. Lord Leigh for permitting the members and ladies to visit Stoneleigh Abbey.

To the Mayor and Corporation of Worcester for their civic welcome; to the Very Rev. Dean of Worcester for permission to visit the Cathedral; to the Worcester Royal Porcelain Co., for permission to visit their works; and to Mr. Joseph Littlebury for his reception and address at "Ye Antient Commandery"; and to Mr. C. J. Seaman for arranging the visit to Worcester.

To the Very Rev. Dean of Lichfield for permission to visit the Cathedral; to Councillor Charles Harradine, chief verger, for conducting the members and ladies over the Cathedral; to Councillor William A. Wood, Chairman of the Johnson Birthplace Committee, for conducting them over Dr. Johnson's house; and to Alderman Herbert M. Morgan, for inviting them to the Old Grammar School house, Lichfield.

To the Council of the University of Birmingham for the reception and entertainment of the members and ladies at the new buildings.

To Mr. George Tangye for his invitation to visit the Watt room at his residence.

To Messrs. Alfred Herbert, the Daimler Motor Co., and to the Wolseley Tool and Motor Car Co., for inviting the members to visit their works, and for their kindness in entertaining the members at luncheon.

To the Honorary Local Secretaries, Mr. Fred. M. Lea and Mr. Howard Heaton, for planning numerous visits to places of interest in Birmingham and neighbourhood, and for the admirable arrangements which their forethought and energy have provided during the meeting.

To the London and North Western, the Great Western, the Midland, and other railway companies of Great Britain for special traveling facilities connected with the meeting.

The Secretaries of the two societies were instructed to transmit these resolutions to the various corporations and individuals and Professor Hutton voiced their support by the American members. The resolutions were carried by acclamation.

Wednesday Afternoon and Evening

Wednesday afternoon, after luncheon again served in the the Town Hall, was also spent in sightseeing. Many availed themselves of the opportunity to visit the new buildings of the University of Birmingham, opened in July 1909 by the late King Edward, which is splendidly equipped for the study of chemistry, physics and mechanical, civil and electrical engineering. No small part of the formation of this, the leading technical college in Great Britain, was due to the genius and untiring efforts of Mr. Joseph Chamberlain, who in 1898 in a public announcement planted the seed of which this great group of buildings is now the harvest. It was at the suggestion of an

American citizen, Mr. Andrew Carnegie, by whom a donation to the fund was made, that a committee was sent to investigate the work done in America, as a result of which the American system of engineering was introduced into the University by its Council. Sir Oliver J. Lodge, a man of broad sympathies and of world-wide scientific reputation has as its Principal done much by his remarkable personality to realize Mr. Chamberlain's ideal that the University "be not only a school of general culture but practically assist the prosperity and welfare of the district by attention given to teaching science in connection with its application to local industries and manufacturies." On arrival at the University the party were received on the steps by Sir Oliver J. Lodge and in the rotunda by the Vice-Chancellor, Alderman C. G. Beale the Pro-Vice-Chancellor, Alderman F. C. Clayton; the Vice-Principal, Prof. R. S. Heath, and the Professors. The buildings and grounds were fully inspected and after tea served on invitation of the Council of the University in the Great Hall, a magnificent edifice in which all public ceremonies are held, the guests returned to Birmingham in the special motor omnibuses provided for the trip.

A trip was made by others to the brewery of Messrs. Mitchells and Butlers, at Cape Hill, Smethwick, under the guidance of the deputy Chairman, W. Walter Bulter. The malt used in the manufacture of beer is produced on the premises, and the beer when finally manufactured is run into casks by a special apparatus which ensures absolute cleanliness. A display of the company's Volunteer Fire Brigade, which has won several prizes, was given in the presence of the visitors. The directors provide for the recreation of their employees in bowling greens, cricket grounds and a football field, as well as rooms for ambulance practice, lectures, etc. Conveyances and refreshments were offered to the sightseers through the courtesy of the company.

The reception given by the Lord Mayor and Lady Mayoress in the Council House on Wednesday evening, was largely attended and much appreciation expressed of the beauty of the floral decorations and the excellence of the music. The Council House contains a large reception room and art gallery besides the Council Chambers, and all of these were thrown open to the guests. Refreshments were served in the gallery at the conclusion of the reception, and the guests conveyed to their hotels in special motor omnibuses. The Lord Mayor and Lady Mayoress, who personally attended the

various functions, not only contributed much to the occasion by their presence but very effectively emphasized the cordiality of our reception.

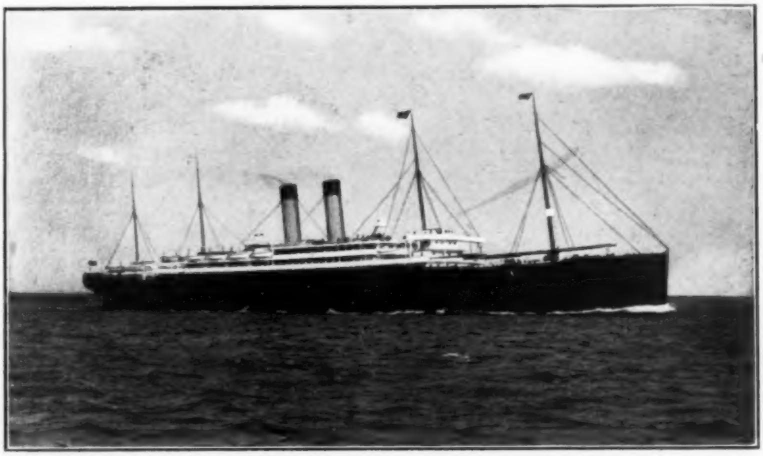
THURSDAY, JULY 28

Both organizations bade farewell to Birmingham on Thursday morning with many expressions of appreciation of their delightful sojourn and regret at leaving the many friends who had made them welcome. The entire day was devoted to sightseeing, all the plans, which provided for four alternative excursions, having as an objective point the arrival of the members in London that same evening, where on Friday and Saturday the final sessions of the Joint Meeting were to be held.

The guests on one of these trips visited Coventry where the Edgwick Works and Foundry and also the Head Works of Messrs. Albert Herbert were inspected under the personal guidance of Mr. Herbert himself, Member of the Institution. This firm manufactures horizontal and vertical milling machines, capstan lathes, automatic screw and turning-machines, light drilling-machines and universal grinding machines. Piece work is employed throughout, a separate price being given for each operation. On Mr. Herbert's invitation the party took lunch in the new building of the company.

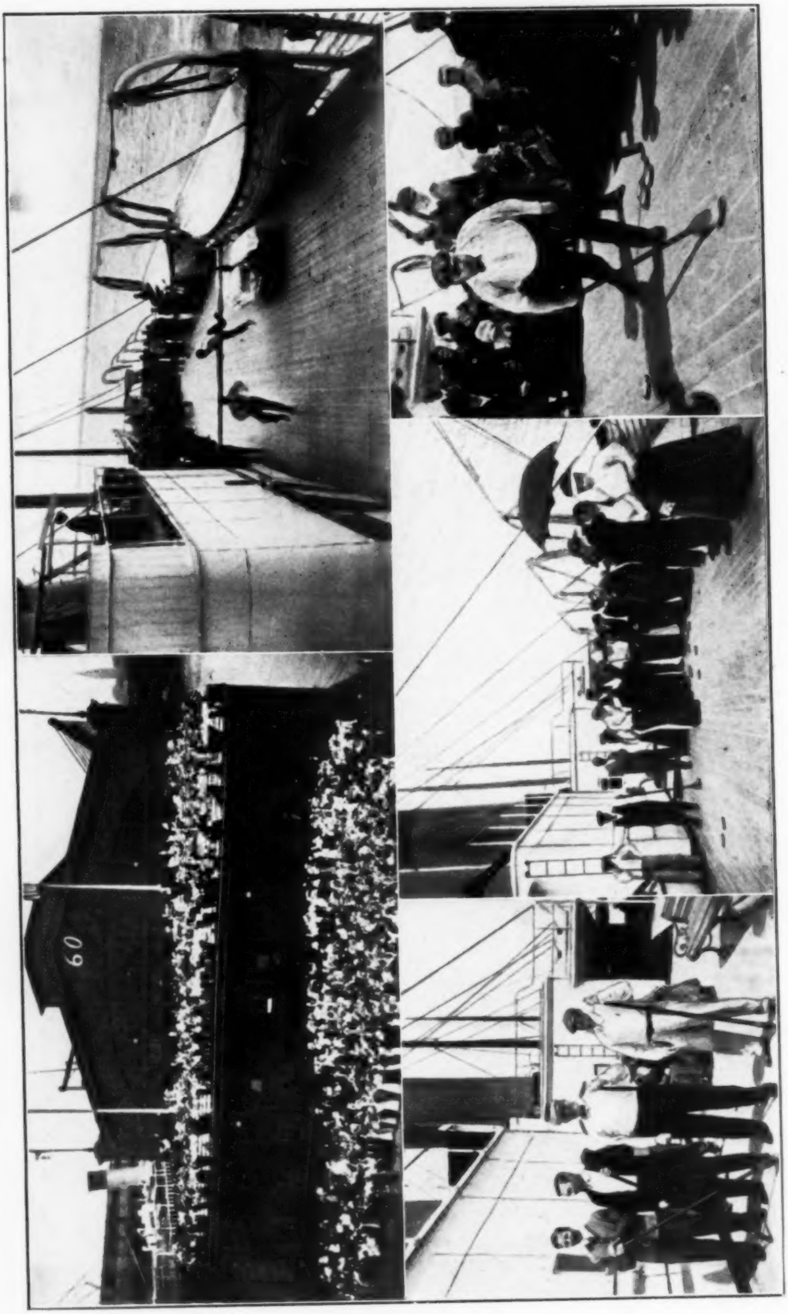
Some of the party on arrival in Coventry went instead to the works of the Daimler Motor Company where they were escorted through the buildings by Percy Martin, Esq., Member of the Institution, and were interested in viewing the thirteen different trades brought into operation at these works, namely, machining, fitting, engine-testing, erecting, copper-smithing, electro-plating, etc., the whole occupying in shops alone 8½ acres of floor-space. The company had provided luncheon for the party which was served at the works.

From Coventry the party proceeded to Rugby, where one group visited the works of Messrs. Willans and Robinson, under the guidance of the general manager, James C. Peach, Esq., Member of the Institution, the principal output of these works being steam turbines, steam and oil engines, condensing plants and pumps. Others inspected the works of the British Thomson-Houston Company, with the chief engineer, H. N. Sporborg, Esq., as escort. This company manufactures electrical apparatus and Curtis turbines for traction, lighting and power purposes.

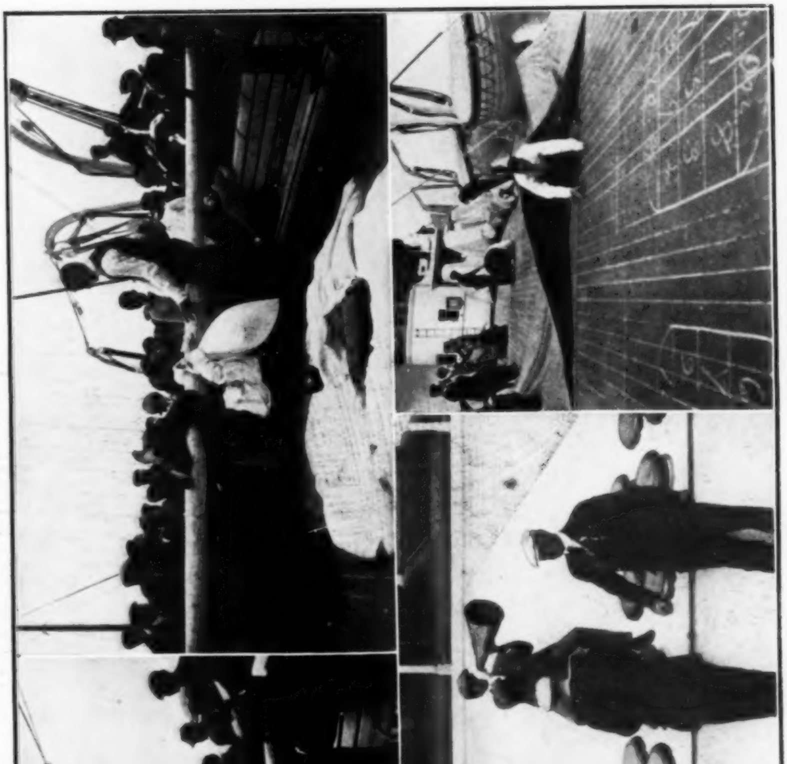


S.S. Celtic, White Star Line, the Official Ship

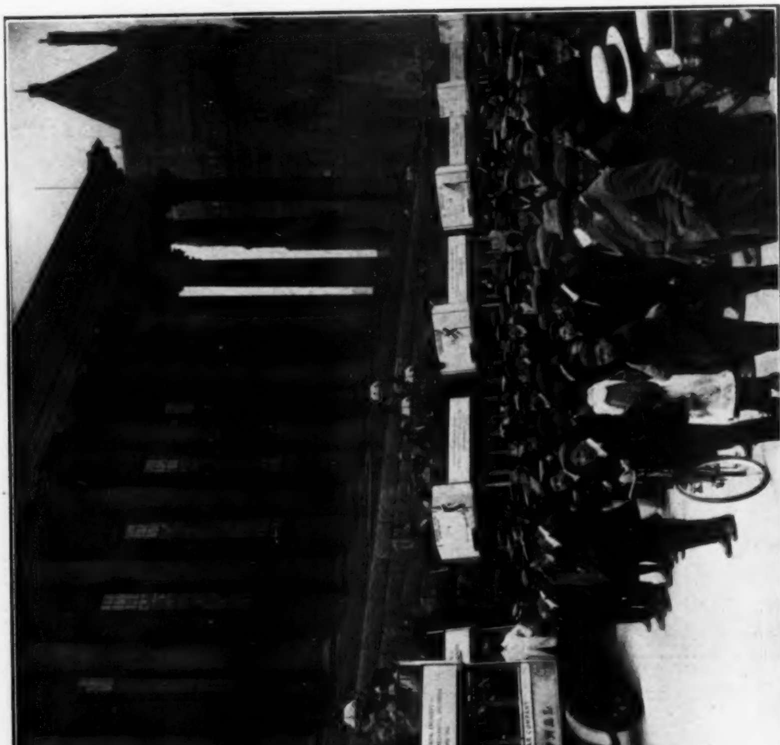
Capt. A. E. S. Hambelton, Commanding S.S. Celtic



SCENE ON THE DOCK AT DEPARTURE AND VIEWS ON BOARD SHIP

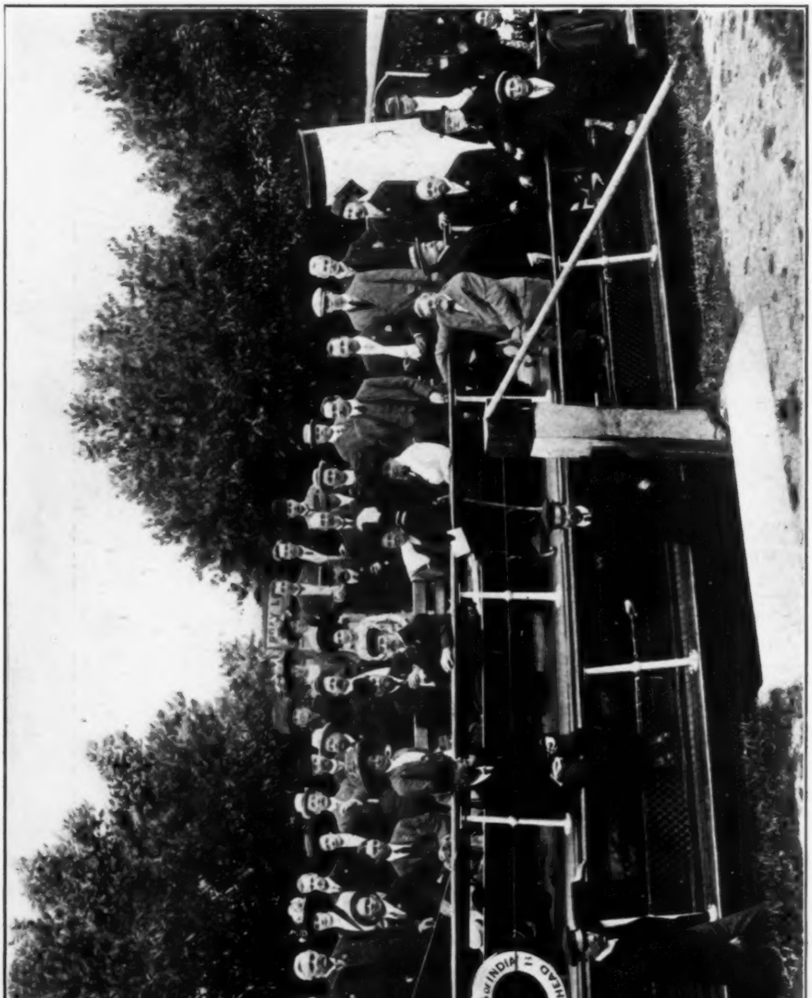


The Sports on Board the Celtic



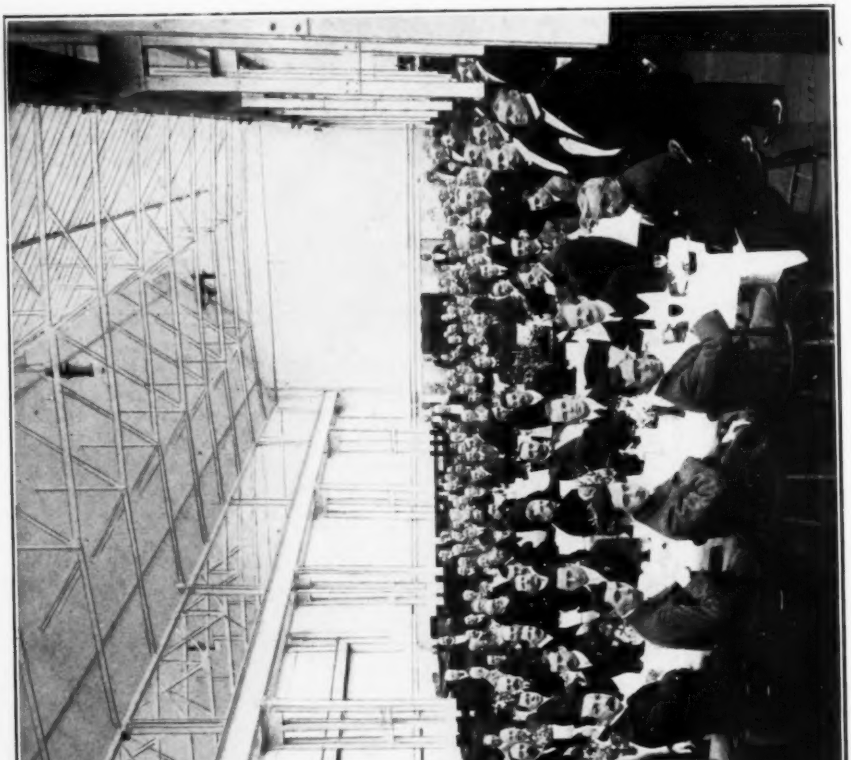
Midland Institute, Birmingham, and Motor Buses which Conveyed Members and Guests to and from their Hotels

The Watt House at Heathfield
Group of Members and Guests Entertained by Mr. Tangye



On the Thames River, on Board the "Empress of India"

ON THE THAMES RIVER, ON BOARD "HIS MAJESTY"



VISIT TO THE WORKS OF ALFRED HERBERT, LTD., COVENTRY
The Employees' Dining Room where the Party had Tea

Another trip took the sightseers to Lichfield, stopping at Hammerwich en route, where under the guidance of the engineer, H. Ashton Hill, Esq., they visited the Pipe Hill Pumping Station of the South Staffordshire Water Works Company, which supplies a population of nearly three-quarters of a million. At Lichfield they were shown through the finely-proportioned three-spired cathedral one of the best existing types of the fourteenth century English church, by the chief verger, Councillor Charles Harradine. This edifice is constructed of red sandstone and the western façade, the principal entrance, has a wonderful richness of decoration. In this same town also, Dr. Samuel Johnson was born and the party were fortunate in viewing his birthplace under the guidance of the Chairman of the Johnson Birthplace Committee, Councillor William A. Wood. In the middle of St. Mary's Square, facing his father's house, is a colossal statute of of the doctor himself, which looks down upon the spectator from a pedestal ten or twelve feet high. Alderman Herbert M. Morgan, ex-Mayor of Lichfield, took the visitors through the Old Grammar School, where Johnson, Addison, Elias Ashmole, Garrick and Darwin once sat upon the rude benches and no doubt spent many uncomfortable hours.

Other members of the Society visited the works of the Wolseley Tool and Motor Car Company at Adderly Park, about two miles from the centre of Birmingham, which devotes exclusive attention to the manufacture of motor-cars and petrol engines for marine, aeroplane and various purposes, and is equipped with high-class machine tools.

The rest of the travelers made a trip to Kenilworth, Warwick and Stratford-upon-Avon, one group proceeding first to Kenilworth, thence to Guy's Cliff and Warwick, and concluding with a visit to Stratford; and the other going first to Stratford and from there to Warwick and Kenilworth, the two parties passing each other en route. In one case luncheon was procured at Warwick, and in the other at Stratford, in the old Red Horse Hotel which an American finds it impossible not to associate with our own Washington Irving.

At Kenilworth the party viewed the magnificent ruins of the old castle, so full of memories of the days of Elizabeth and of her courtier, the Earl of Leicester. The picturesque Guy's Cliff, which contains the cave in which Guy, first Earl of Warwick, is fabled to have passed his latter days and to have been buried, formed a fitting introduction to the gray towers of Warwick which King

Cymbeline is said to have founded at the beginning of the Christian era. The river Avon, which flows before the castle, so perfectly reflects it in its depths that Hawthorne's fancy with regard to the reality of the mirrored image and the unreality of the upper structure seems amply justified. Through the courtesy of the Earl of Warwick the castle with its many historic relics and architectural beauties was thrown open to the visitors.

At Stratford-upon-Avon, now a successful place of business and often for that reason a disappointment to the visitor because of its "newness," the party visited Shakespeare's birthplace where the beholder must always marvel at the humble surroundings of the man whose splendid imaginings have so peopled our world; the church in which stands his tomb engraved with the famous "curse"; Anne Hathway's Cottage of much the same rude order as Shakespeare's house; and the Memorial Theatre, a more modern structure. On all of these excursions as on the previous day, the amplest provision and care had been made for the conveyance and refreshment of the travelers.

More than 800 guests, even after this strenuous day, assembled in the evening at the delightful Conversazione given in the rooms of the Institution. This building, which has been erected since the former visit of the American members to England in 1889, was much admired by all for the beauty of its architecture and decorations and for its fine site overlooking the waters of St. James Park. President and Mrs. Aspinall received the guests in the large hall which is decorated with Hungarian oak panellings, surmounted by red walls and enriched ceilings. During the evening, music was rendered here and in the library by the band of the Royal Artillery and by several fine vocalists. A short lecture illustrated by lantern slides was given by Dr. H. S. Hele-Shaw, on Stream Line Experiments Illustrating Aeroplane Stability. Refreshments were served in the Marble Room.

FRIDAY, JULY 29

The concluding professional session of the Joint Meeting was held on Friday, in the Institution House of the Civil Engineers, which is diagonally opposite the headquarters of the Mechanical Engineers. On account of the fatigue of the previous day the attendance was small, but those who were present were repaid by the opportunity

of meeting in the dignified rooms of the Institution and of participating in the discussion of especially able papers on Electric Traction. The societies were welcomed by Mr. Alexander Siemens, Senior Vice-President, who expressed the Institution's great pleasure in thus offering to the Joint Meeting the use of their theatre. President Aspinall responded and in expressing his thanks spoke of the improbability that another such gathering would be held in the historic building, because of the early occupation by the Institution of their new home. Dr. Goss, on behalf of the American members, spoke of the charm such a building had for those from a newer environment and of their appreciation of being able to gain some acquaintance with the Institution.

The following papers were then read in abstract: Electrification of Suburban Railways, by F. W. Carter, of Rugby; The Cost of Electrically-Propelled Suburban Trains, by H. M. Hobart, of London; Economics of Railway Electrification, William Bancroft Potter, Mem.Am.Soc.M.E., Engineer, Railway and Traction Department, General Electric Company, Schenectady, N. Y., presented by H. H. Barnes, Jr., of New York; The Electrification of Trunk Lines, by L. R. Pomeroy, Mem.Am.Soc.M.E., J. G. White, Co., Inc., New York, N. Y.; The Electrification of Railways, by George Westinghouse, President Am.Soc.M.E., Pittsburg, Pa., presented by Charles F. Scott, of Pittsburg. These were discussed by Charles F. Scott, H. F. Parshall, J. Dalziel, Sidney Stone, Edgar Worthington, H. M. Hobart, Angus Sinclair, J. G. Wilson, F. R. Hutton, F. W. Carter, H. H. Barnes, Cary T. Hutchinson, and J. R. Williams.

The following resolutions of thanks were then put to vote and carried by acclamation:

To Dr. and Mrs. Maw and Sir John and Lady Thornycroft for their kind invitations to the members and ladies to attend garden parties.

To The Times for the invitation to visit their printing works.

To the Council of the Institution of Civil Engineers for so kindly placing their lecture hall at the disposal of the members for the purposes of the London meeting.

To His Worship the Mayor of Windsor, Councillor C. F. Dyson, for courteously lending the Guildhall for the purposes of the luncheon in Windsor; also to His Worship and Mr. George Mitchell, Mr. Christopher Sainty and Mr. George Willis for conducting the members and ladies at Windsor.

That the Secretaries of the Institution of Mechanical Engineers and The American Society of Mechanical Engineers be severally instructed to transmit the above resolutions to the various corporations and individuals who have

done so much to make the Joint Meeting enjoyable and memorable on both sides of the Atlantic.

Prof. F. R. Hutton made the concluding remarks of the session, speaking at some length of the enjoyment of the American members of the Birmingham and London meetings, and offering the following additional resolutions:

The American Society of Mechanical Engineers, present by invitation at the closing session of the Joint Summer Meeting of 1910 with the Institution of Mechanical Engineers, asks permission to offer for record the following minute and requests its Acting President to put the resolution to vote:

The American Society of Mechanical Engineers has been enveloped in an atmosphere of courteous, friendly, and devoted attention from the moment that the vessel which carried the official and organized party entered the River Mersey at Liverpool. Beginning with a reception on the steamer, at which the President and Secretary of the Institution officially welcomed the party, in conjunction with representatives of the city and other interests of that progressive corporation, and continuing through the arrangements for comfortable and convenient transportation by train to the place of first meeting; providing on arrival for prompt and satisfactory hotel accommodation, and for organizing, in a masterly way, which extended even to the most minute details for the enjoyment of the visitors on excursions, in affording opportunities to visit works, for transportation, and for motor drives in the historic Midlands of England, the Institution of Mechanical Engineers has placed The American Society of Mechanical Engineers under an obligation which no mere words or resolutions are an adequate medium to discharge. The visitors can only assure the home Society, its President, its Council, its Secretary and its organizing committee that just because they are themselves organizers and doers they are able most thoroughly to appreciate such work well done.

The American Society also appreciates most sincerely the generous purpose which has spared no sacrifice when the desired object of the hosts has had to be met by the ordinary commercial procedure as respects outside parties. Hence the Society moves and seconds the following resolutions:

Resolved, that The American Society of Mechanical Engineers desires, in addition to the resolutions passed in Birmingham thanking those who had put both bodies under a pleasant debt of obligation, to put on record the following special resolutions of thanks:

Resolved, that The American Society thanks the Institution of Mechanical Engineers, its President, Council, Secretary and Committee for their ceaseless, unremitting, and painstaking effort for the pleasure and success of the Joint Meeting of 1910 in Birmingham and London.

Resolved, that this Joint Meeting will be a memory of delight and pleasure for all the Americans who have been privileged to share in it.

Resolved, that The American Society of Mechanical Engineers desires to thank the Birmingham Reception Committee for certain special considerations at their hands, which were extended exclusively to the American members of the Joint Party, and requests the Institution to be the channel for conveying such action of thanks.

Resolved, that The American Society of Mechanical Engineers desires by this action to express for the ladies, who have accompanied the members, something of the appeciation of both members and ladies for the delicate and considerate attention which has made their participation a delight and a possibility. The members feel that international friendships springing from these days of close and enjoyable association are sure to last forward into future happy years.

Resolved, that The American Society of Mechanical Engineers requests the Institution of Mechanical Engineers to incorporate this minute and action as part of its record of the Proceedings of the Joint Summer Meeting of 1910.

These were carried by the rising vote of all the Americans present.

Friday Afternoon and Evening

Two very enjoyable garden parties were given on Friday afternoon, one at the home of Dr. William H. Maw, Esq., Past-President of the Institution, and Mrs. Maw, at Addison Road, Kensington, and the other at Eyot Villa, in Chiswick Mall, the home of Sir John Thornycroft, Member of the Council, and Lady Thornycroft, at both of which the visitors were given a delightful glimpse of English home life.

A number of members also inspected the British Museum, and the Times Office in Printing House Square through which they were conducted by the Chief Engineer, J. P. Bland, Esq., Member I.Mech.E. These offices stand on the site of the building from which the paper was first issued in 1785.

An event to which the American members had looked forward with much delightful anticipation was the banquet given by the Institution on Friday evening in the Connaught Rooms, the largest dining hall in the city of London. After the usual toasts to the Crown had been given, President Aspinall proposed The President of the United States, which was acknowledged by the American Ambassador, the Hon. Whitelaw Reid. Mr. Reid said that he regarded this toast not only as a tribute of high regard for the personal character of the present occupant of the Presidential chair, but also a token of profound respect for the whole country over which he ruled, and that he believed the material conquests which had created and developed the great empire of America, occupying more than one-quarter of the habitable surface of the globe and comprising nearly one-third of its inhabitants, were due to no class more largely than to the mechanical engineers of the two countries represented at this gathering.

Sir William H. White in giving the toast, The American Society of Mechanical Engineers, recalled the fact that it was founded but 30 years ago and yet had now a membership of about 4000. He referred particularly to the long years of service for the Society of Prof. F. R. Hutton, who, he said, had together with the present Secretary, promoted the Society's growth and success, and that by virtue of their ideals for its welfare the American organization was safe in their hands. Professor Hutton in responding said that the present gathering was the culmination of a series of meetings of mechanical engineers on both sides of the Atlantic, and that the profession which they represented underlay the civilization of the Anglo-Saxon race. The American was much at home in the United Kingdom because he and his host had a common ideal.

A toast to Our English Guests, proposed by Edward B. Ellington, Vice-President of the Institution, was acknowledged by Dr. R. T. Glazebrook, Director of the National Physical Laboratory; and the final toast of the evening, The Institution of Mechanical Engineers, given by Dr. W. F. M. Goss, was answered by President Aspinall.

Among the guests of the evening were James M. Dodge, Oberlin Smith, A. H. D. R. Steel-Maitland, M. P., Dr. Worcester, Mr. and Mrs. J. Hartley Wicksteed, Mr. and Mrs. F. W. Taylor, Dr. and Mrs. Wm. Maw, Charles Hawksley, the Lord Mayor and Lady Mayoress of Windsor, E. P. Martin, Mr. and Mrs. Ambrose Swasey, Charles Kirchhoff, J. L. Griffiths, United States Vice-Consul, Mr. and Mrs. John R. Freeman, Sir Gerard and Lady Muntz, Henry Lea, C. F. Scott, Mr. and Mrs. Jesse M. Smith, Mr. and Mrs. James Hartness, Mr. and Mrs. Wm. H. Wiley, Calvin W. Rice, Mr. and Mrs. Willis E. Hall, Mr. and Mrs. Henry L. Gantt and Dr. Hele-Shaw. Music was furnished during the evening by the Imperial Orchestra.

SATURDAY, JULY 30

All-day excursions to Windsor and Marlow occupied Saturday, half of the party leaving London by special train for Windsor and proceeding by the special steam launches, Empress of India and Majestic, to Marlow, and the other half going by train to Marlow and thence to Windsor by the launches, His Majesty and Princess Beatrice; the two groups passing each other on the river. A view of the two parties is given herewith. In one case luncheon was served in Windsor at the Guildhall, with tea at the Compleat Angler and George and Dragon Hotels in Marlow, a picturesque fishing resort;

while in the other the party had luncheon on the launches and tea in the Guildhall. The trips on the launches were most enjoyable and gave a complete idea of life on the Thames, including the famous Henley regatta, then in progress. At Windsor, the Lord Mayor, Councillor C. F. Dyson, Alderman George Mitchell, Mem. I.Mech.E., Christopher Sainty, Mem.I.Mech.E., and George Willis, Assoc. Mem.I.Mech.E., personally conducted the party about this favorite residence of the English monarchs.

On Saturday evening Sir William H. White, Past-President of the Institution and an Honorary Member of the Society, together with Lady White entertained the Councils of the Institution and the Society at dinner in the Garden Club, which overlooks the grounds of the Japan-British Exposition at Shepherd's Bush. The picturesque Japanese Gardens, with their flavor of old-world romance, and the fine exhibits of ancient and feudal Japan, contrast strongly with the wonderful modern enterprise of both nations, and make the spot vastly interesting. Many Americans took advantage of the opportunity to see this Exhibition, assembling later in the room which had been especially set aside for the purpose by those in charge.

SUNDAY, JULY 31

Interest has long been manifested by the Society in the Sir Benjamin Baker Memorial Window in Westminster Abbey, which was unveiled on Dec. 3, 1909, and it was a pleasure to have an opportunity on Sunday evening of viewing it. The window, which is situated on the north side of the Nave, contains two lights having the figures of King Edward III and Abbot Simon Langham, under canopies, both lights being framed with borders containing niches which hold twelve statuettes and as many shields. Below these is the inscription on tablets held by the figures of angels: IN MEMORY OF SIR BENJAMIN BAKER, CIVIL ENGINEER, FORTH BRIDGE, ASSUAN DAM. B. 1840. D. 1907. The members assembled in the Dean's Yard and were conducted through the Abbey with its many famous spots by the Sub-Dean, the Very Reverend Dr. Duckworth. At the Vesper Service in the Nave, at seven o'clock, seats had been assigned to the representatives of the two societies and in his sermon the Bishop of Lewes gave a special greeting to the American visitors, of which 250 were present.

Taking his text from I Cor. xxii. 5, "There are differences of administration, but the same Lord," the Bishop declared this to be the

exact opposite of the theory that everybody ought to be alike. Each had his special place and value, which were appraised differently by men but not by God. There were also differences of method, and not all seemed unsuccessful. Here amidst the memorials of the mighty dead we were never allowed to forget for one moment the vast range of God's workings in the life of men. Men great in war and great in peace, men far from perfect, each humanly weak, were here, but here because of the power of ministration that was in them. Differing widely in gift, method, opportunity, they were united in being searchers after the truth, interpreter's of God's plans and purposes for man, men who tried to serve their generation by the will of God. Sir Benjamin Baker was such a worker in the field of engineering service. The builder of Forth Bridge hardly needed any further remembrance, but as a man of noble character, as well as a scientific genius, he belonged among those who shared his talents and his strenuous life to interpret God's plans to men.

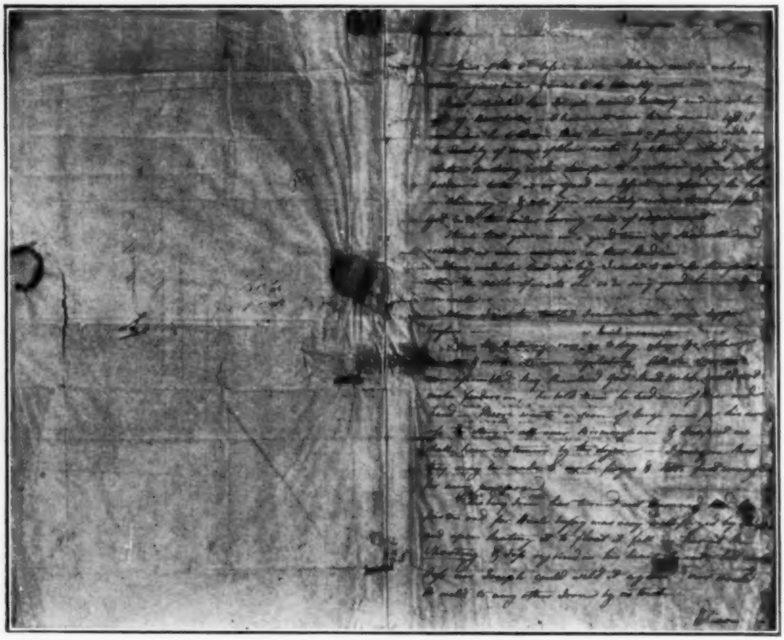
This service was regarded as the benediction of the Joint Meeting in England, which could not have been more appropriately ended.

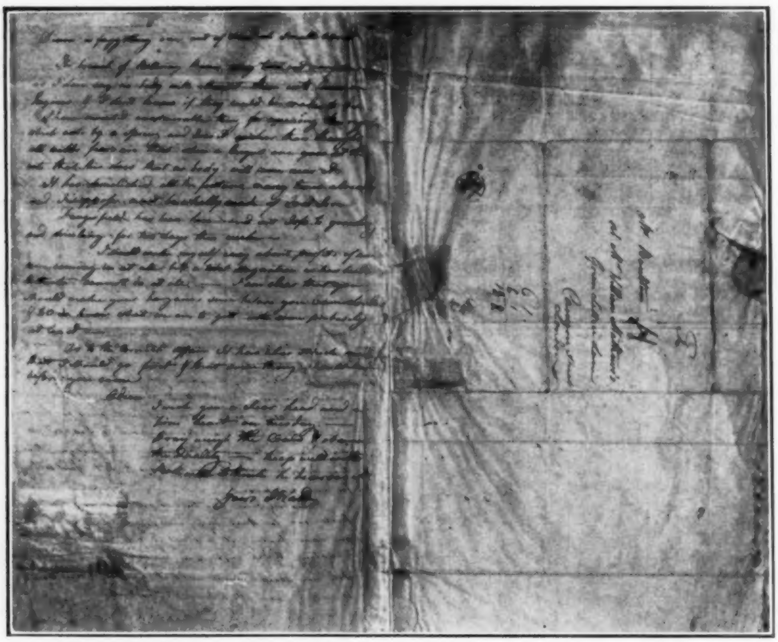
On Monday evening, on the eve of departure on their second world tour, Ambrose Swasey, to whose forethought, wonderful tact and administrative ability it is not too much to say that a great part of the success of the Society's trip to England is due, together with Mrs. Swasey gave a dinner to the members of the Council of the American Society in the Hotel Russell, London. Leave takings were general on every side, some of the party going on to the Continent and others returning at once to America.

Among the kindly messages received during the Joint Meeting was the following telegram from the Junior Institution: "President Sir Henry Oram and Council Junior Institution Engineers desire join expressions welcome American Society Mechanical Engineers on visit Great Britain." Every member also received from the President of the Institution of Mechanical Engineers a very handsome brochure, containing portraits of the Presidents of the two organizations represented at the Joint Meeting, and brief biographical sketches of George Stephenson, Matthew Boulton, James Watt, Richard Trevithick, Robert Fulton, and William Symington, profusely illustrated with portraits and with quaint designs reproduced from Stuart's Anecdotes of Steam Engines, published in 1829.

Such an account as is here presented can give but a glimpse of the visit to England, remarkable for its comfort and sociability and for the vast entertainment provided by the English Society, presenting

as it did a happy combination of the technical and social features which were all blended together in the increased mutual regard, as removed from rivalry, of these two great national organizations. As no American can find himself a stranger in this land of his forefathers and his traditions, so no member of a professional organization on this side of the water can come in contact with those of a similar vocation in England without experiencing a sense of common ideals and common aims. Of the wonderful hospitality accorded by the English Institution too much cannot be said; nor can thanks ever express to the British members the gratitude and pleasure of their American guests. Not the slightest detail seems to have been omitted, the machinery of the entire gathering moving so perfectly as to be practically invisible. The finely prepared program, with its maps covering every inch of the ground to be traveled during the meeting, was an illustration of this wonderful attention to detail, including information, in addition to fullest data of meetings and trips, which met every possible want of the traveler, from restaurant locations and cab fares to the dates of departure of steamships carrying mails. The many welcoming hands held out on every side made the meeting a homecoming rather than a visit, to be looked back upon by all as a red-letter season in the life of the Society. The greeting of the English engineers when they shall next come to American shores, in a way worthy of their own welcome, is already joyfully anticipated by our members.





WATT LETTER PRESENTED TO THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS BY MR. GEORGE TANGYE IN BIRMINGHAM, JULY 26

COUNCIL HOUSE, COLMORE ROW, BIRMINGHAM

COLMORE ROW, BIRMINGHAM

UNIVERSITY OF BIRMINGHAM

Botanical Gardens, Edgbaston

Coventry, Showing the Spires of St. Michael's, St. Mark's and St. John's

LICHFIELD CATHEDRAL FROM MINSTER POOL, SHOWING THE THREE SPIRES

RUINS OF KENILWORTH CASTLE

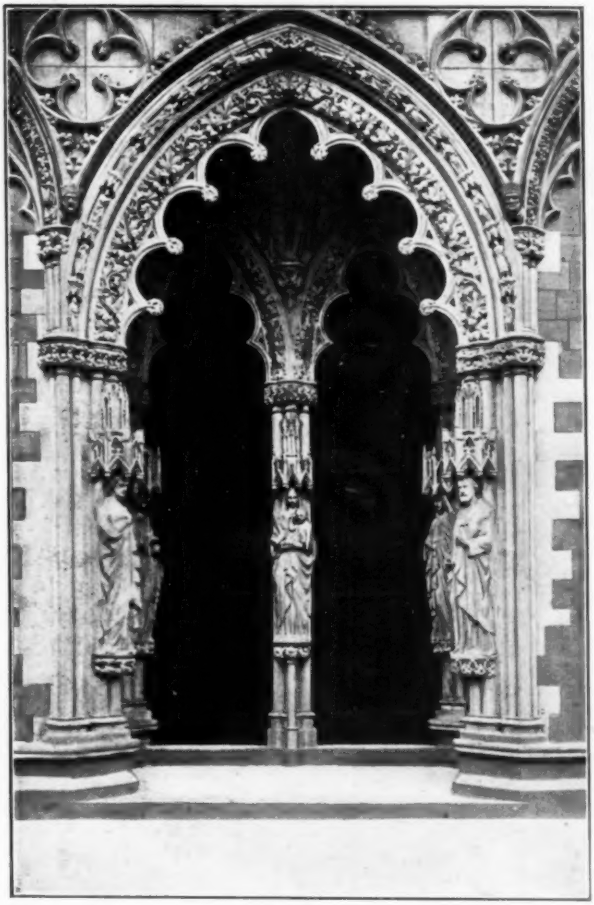
STRATFORD-UPON-AVON

The Shakespeare Memorial Building appears at the right and the Church containing the Tombs of Shakespeare and Anne Hathaway at the left.

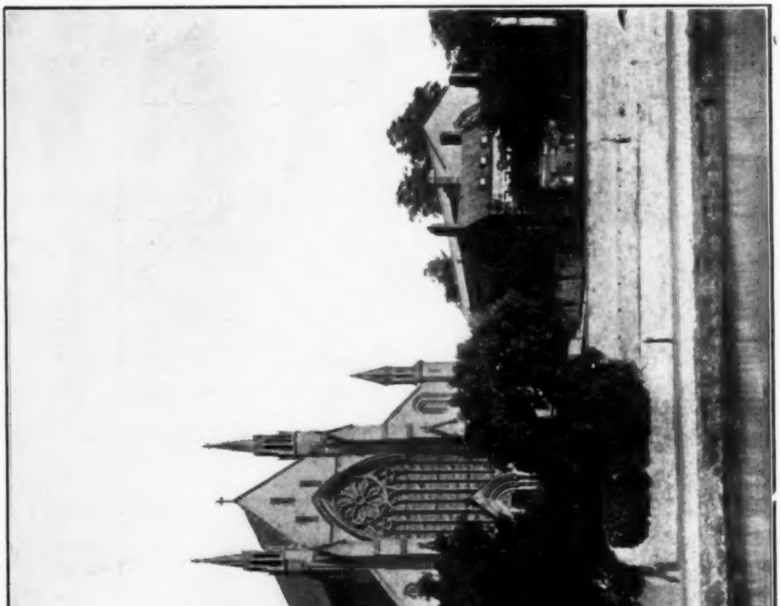
WARWICK CASTLE ON THE RIVER AVON

SHAKESPEARE'S HOUSE, STRATFORD-UPON-AVON

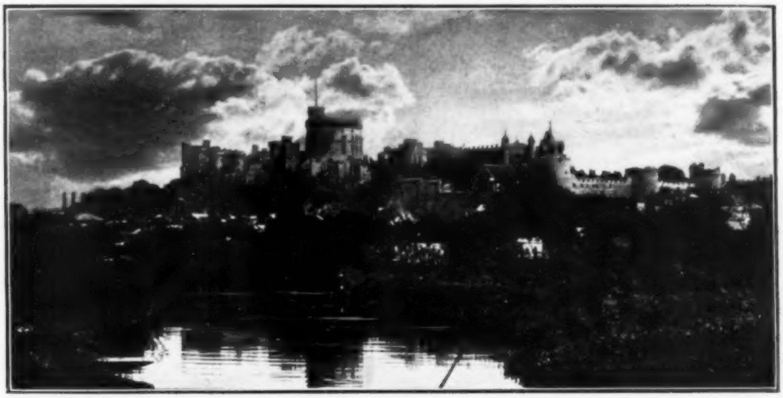
ANNE HATHAWAY'S COTTAGE, STRATFORD-UPON-AVON



Lichfield Cathedral, Showing the West Door, Its Main Entrance

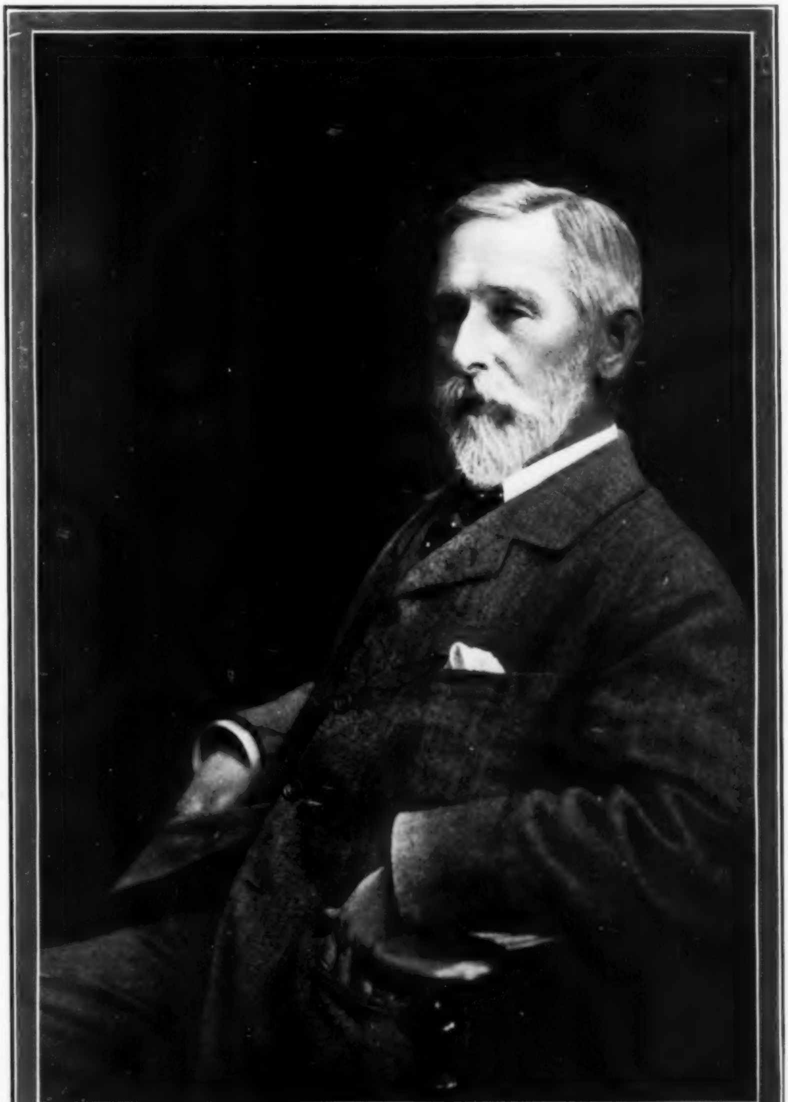


WORCESTER CATHEDRAL



Windsor Castle from the Thames

Westminster Abbey, West Towers



Mr. George Tangye, Esq.

Who Presented to the Society the Watt Letter

RIGHT HON. JOSEPH CHAMBERLAIN

FORMER CHANCELLOR OF THE UNIVERSITY OF BIRMINGHAM, WHO STARTED THE MOVEMENT FOR ITS ESTABLISHMENT

Sir Oliver J. Lodge
Principal of the University of Birmingham

Alderman C. G. Beale
Vice-Chancellor of the University of Birmingham

THE TRANSMISSION OF HEAT IN SURFACE CONDENSATION

By George A. Orrok

TABLE OF CONTENTS

Historical Introduction 1773
Present Status of Heat Transmission through Metallic Tubes ... 1773
Methods and Apparatus 1775
Outline of Tests 1780
Variation of Heat Transfer with Temperature Difference 1784
Variation of Heat Transfer with Velocity of Water 1789
Variation of Heat Transfer with Velocity of Steam 1791
Effect of Air upon Heat Transmission 1794
Conclusions 1795

LIST OF APPENDICES

No. 1 List of Symbols Used and Tables Relating to Tests Made by the Author 1798
No. 2 Review of Results Obtained by Different Experimenters .. 1824
No. 3 References to Published Articles on Transmission of Heat through Tubes 1831

THE TRANSMISSION OF HEAT IN SURFACE CONDENSATION[1]

By George A. Orrok, New York
Member of the Society

Ever since the first use of steam in the arts, the condenser has been a very important part of the machinery designed for its utilization and the very simple laws governing condensation by mixture were early understood and formulated. With the advent of the surface condenser the problem became more complicated and the laws governing the transmission of heat through tubes or plates from wet vapor or condensing steam to water have been investigated by many physicists from Poisson in 1835, Peclet in 1841 and Joule in 1861 down to the present time. The earliest statement of the law of heat transmission in solids was made by Newton in 1690, while most of the mathematical work has been based on Fourier's classic published in 1882. Most of the earlier experimenters were misled by defects in their apparatus but by 1870 the existence of the gas film on the steam side of the tubes was suspected. The existence of the water film was suspected as early as 1861. Sir William Thomson stated in 1880 that the work of the earlier investigators was vitiated by the assumption that the temperature of the metallic surfaces was the same as the temperature of the medium in contact with them.

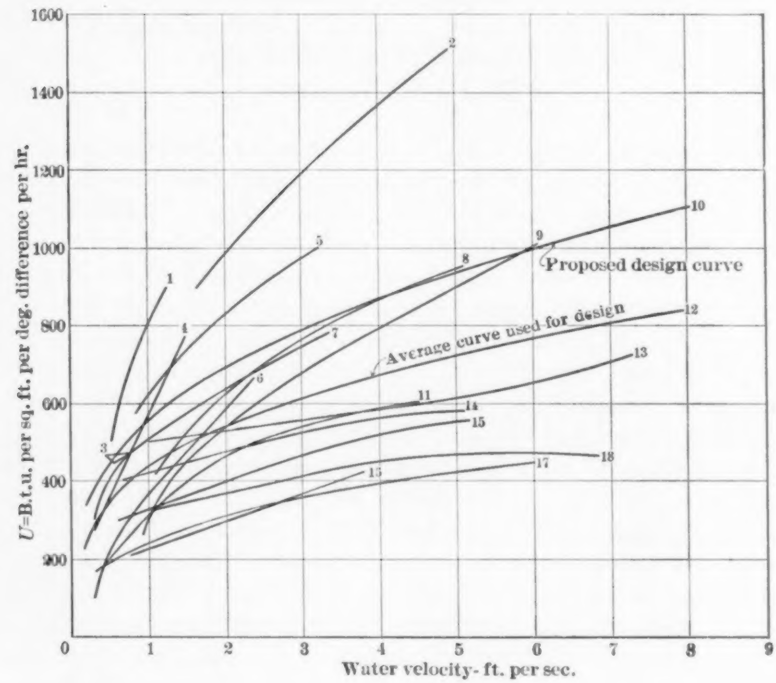
2 Since 1880 there have been attempts to ascertain the laws of heat transmission for condenser practice by many investigators: Werner and Hagemann in 1883, Ser in 1887, Richter in 1899 and Hepburn in 1901. The later experimenters have worked with actual machinery along what might be termed commercial lines.

3 The present status of the transmission of heat through metallic tubes from condensing steam to water according to various authorities may be stated as follows:

[1] For list of Symbols used see Appendix No. 1

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

a The quantity of heat transmitted by a unit of surface in unit time is proportional to the temperature difference (Joule, Rankine and most of the experimenters) or to the square of the temperature difference (Werner, Grashof and Weiss) between the media on the different sides of of the tube.



1—Josse—top of condenser
2—Josse—top of condenser (with baffles)
3—Richter—corr. copper tubes (horiz.)
4—Hepburn—corr. copper tubes (horiz.)
5—Josse
6—Hepburn—plain copper tubes (horiz.)
7—Ser
8—Weighton—plain tubes
9—Josse
10— $U = 22\sqrt{V_s}\sqrt[3]{0.023 + V_w}$ $(V_s = 625)$
11—Hagemann
12— $U = 17\sqrt{V_s}\sqrt[3]{0.023 + V_w}$ $(V = 625)$
13—Nicol—horizontal tubes
14—Stanton—water flowing down
15—Stanton—water flowing up
16—Allen—horizontal tubes
17—Joule
18—Nicol—vertical tubes

FIG. 1 VARIATION OF HEAT TRANSMISSION WITH WATER VELOCITY

b The quantity of heat transmitted is proportional to some power of the water velocity ($V_w^{\frac{1}{2}}$ by Joule and Ser, $V_w^{\frac{1}{3}}$ by Hagemann and Josse, V_w^{1} by Stanton).

c The quantity of heat transmitted is proportional to some power of the steam velocity or mass flow ($V_s^{\frac{1}{3}}$ by Hausbrand and Ser, mass flow by Jordan).

d The quantity of heat transmitted is greatly affected by the amount of non-condensible vapors on the steam side of the tube (Bourne, Smith, Weighton, Morrison, McBride).

4 These differences of opinion did not trouble designers seriously as long as small condensers and vacuums of over two pounds absolute were the rule, but with the development of the turbine the need arose for condensers capable of condensing more than 200,000 pounds of water per hour at an absolute pressure of less than one pound. At first, excessive amounts of surface were installed but the first cost and upkeep led to more careful design and the demand for a more accurate knowledge of the laws of heat transmission under condenser conditions.

5 A careful study of the results of all the experiments available was made and plotted in Fig. 1. These curves show wide variation of values, but for a time the attempt was made to work from an average curve deduced by giving weights to the various experiments depending on the number of individual figures and their consistency. This average curve was used in the design of a number of large installations with excellent results.

6 The need for a careful determination of the whole question still existed and through the liberality of the management of The New York Edison Company the author was enabled to develop the apparatus and make the experiments described below, the results of which confirm and complete much of the work of earlier experimenters. It is hoped that they will aid condenser designers in producing apparatus better suited to the work, more satisfactory and more economical than ever before.

METHODS AND APPARATUS

7 The object in making these tests was to determine the heat transfer through various kinds of condenser tubes and the laws governing its variation under different conditions of steam temperature, pressure and velocity; velocity of circulating water; and mean temperature difference.

8 In order to obtain these data, a small surface condenser was constructed with a relatively small cooling surface and it was operated under conditions as nearly like actual condenser conditions as possible.

The steam inlet, dry vacuum, and circulating water lines were so arranged and controlled that any desired vacuum, any desired velocity of circulating water and any desired mean temperature difference could be maintained and that any one of these conditions could be varied through a considerable range quite independent of the other two. A hot well was constructed and so connected to the condenser that the temperature of the hot-well water (condensed steam) and its amount could be determined. Thermometers, pressure gages and a water meter were installed and a record was made of all desired data.

9 In order to fulfill these requirements, it was found necessary to make numerous changes in the apparatus as first constructed, which is shown in Fig. 2. It consisted of a condenser made of 5-in. extra-heavy wrought-steel pipe, with cast-iron screwed flanges on each end. To these were bolted cast-iron blank flanges, drilled and tapped for the various steam, water and vacuum connections. The condenser was of such a length that exactly 1 sq. ft. of cooling surface on a 1-in. outside diameter condenser tube was included between the inside faces of its end flanges. A condenser tube was passed through the center of the condenser and projected about 4 in. on each end through small stuffing boxes. These stuffing boxes, C_1 and C_2, are shown in detail in Fig. 4. A thermometer well and a vacuum gage connection were installed for recording the steam temperature and pressure. A hot well made of 5-in. wrought-iron pipe with a screwed and a blank flange on each end was connected to the condenser as shown. On the front of the hot well, a gage glass and a graduated scale were placed so that the height of the water could be observed and recorded, making it possible to calculate the weight of steam condensed for any given length of time. The valve G was used to empty the hot well at the end of a test. A thermometer was installed at H for observing the temperature of the condensed steam, the piping being so arranged that there was always a solid body of water surrounding the thermometer well. A ½-in. line connected the top of the hot well to the vacuum line to equalize the pressures. The entire condenser and ¾-in. line to the hot well were covered with 4 in. of magnesia pipe covering to eliminate the effect of radiation.

10 The 1-in. circulating water line was taken from a 6-in. salt-water fire line in which was maintained a pressure of 90 lb. gage. This 1-in. line was connected to the condenser tube at each end by a piece of rubber hose which was wired at the ends to withstand a pres-

sure of about 20 lb. gage. Thermometer wells and thermometers were installed for observing the temperature of the circulating water at the inlet and the outlet of the condenser. The method of installing these thermometer wells is shown in detail in Fig. 4. A water

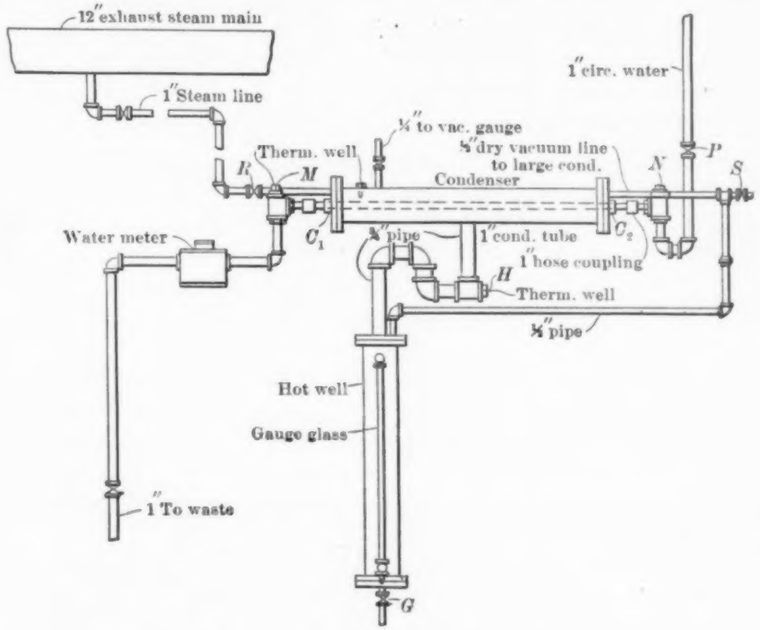


Fig. 2 Apparatus as First Constructed

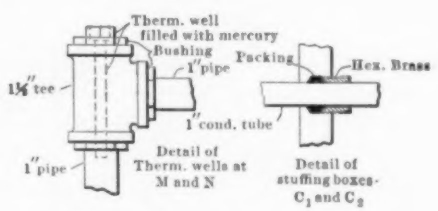


Fig. 3 Fig. 4
Details of Apparatus

meter was installed to register the amount of water flowing. The valve *P* was used to regulate the rate of flow.

11 The 1-in. steam pipe was taken from the bottom of a 12-in. exhaust main which carried the exhaust steam from various auxiliary

engines to an open feed-water heater. The pressure in this line was about 2 lb. gage. The valve *R* was used to regulate the amount of steam admitted to the condenser.

12 The $\frac{1}{2}$-in. dry vacuum line was connected to the hot well of a large surface condenser which was operated at a vacuum of from 27.0 in. to 28.5 in. of mercury, or about 1 in. absolute pressure. All flanged joints were made up with $\frac{1}{8}$-in. rubber gaskets and all screwed joints with a heavy coating of red lead on the threads. One of the greatest difficulties encountered when running tests at a high vacuum was the prevention of air leakage. This difficulty was overcome to a great extent by a frequent and liberal application of a special heavy asphaltic paint to all joints. It was found possible to hold a vacuum within 0.5 in. of mercury of that in the large condenser when all valves were closed, except valve *S* in the vacuum line. With *S* closed, this vacuum would only drop from 27 in. to 26 in. in a period of 5 min.

13 All thermometers used in these tests were of the best make and could be read with accuracy to 0.1 deg. fahr. The water meter used was tested at various times and its error determined for all rates of flow. All heat transfer tests were extended over a period of 10 minutes after conditions had become constant and readings of temperatures and pressures were taken every 3 minutes.

14 A series of tests were made on various kinds of tubes at different vacua, but it was found that the heat transfers calculated from these tests had a maximum variation of 20 per cent for the same tube under exactly the same conditions as to steam temperature and pressure, mean temperature difference and velocity of circulating water. In these tests the vacuum was varied by regulating the steam admitted through the valve *R*, the vacuum line being kept wide open. It was found that to maintain a higher vacuum than 24 or 25 in. of mercury the steam valve *R* could be opened only a very small amount and that the steam entering the condenser was superheated as much as 50 deg. fahr. Another difficulty encountered was that at low vacuum, when the valve *R* was almost wide open, the heat transfer figured from the amount of steam condensed as measured in the hot well was considerably higher than that figured from the heat absorbed by the circulating water. This showed that the steam admitted must have contained considerable moisture. It was also found very difficult to maintain the rate of flow of the circulating water constant, due to the variation in pressure in the fire line from which it was taken. To overcome these difficulties, a number of

changes were made in the piping. A separator was installed in the steam line and the line was taken from the top of the 12-in. exhaust main instead of from the bottom. To aid in controlling the rate of flow of the circulating water, a pressure gage was installed in the line, and to maintain a constant rate of flow it was necessary only to keep this pressure gage indicating a steady pressure by regulating inlet valve *P*. In order to make it possible to maintain a high vacuum in the condenser without undue throttling of the steam, the dry vacuum line was increased in size to a 1-in. pipe.

15 Another series of tests was then made and it was found that the moisture in the steam at low vacua was practically eliminated. It was also possible to maintain a high vacuum, although there still seemed to be a more or less uncontrollable degree of superheat and the heat transfers for these high vacua tests were considerably lower than those at the lower vacua. A water jacket was now placed on the steam line with a $\frac{1}{2}$-in. water connection from the circulating water line. This arrangement seemed to have but slight effect, however, and there was still found to be a considerable variation in heat transfer when an attempt was made to duplicate tests.

16 It was decided that the difficulty must lie with one of the following things:

a The quality of the steam as to amount of superheat, moisture, or entrained air and oil.

b The circulation or velocity of the steam.

c Air leakage.

d Cleanliness of the tubes.

17 To take care of the first item, it was decided to build a small independent boiler and generate steam as it was needed by means of a high-pressure steam coil. The boiler was constructed of two 14-in. flanged tees bolted together, with blank flanges bolted on the ends. It was connected to the condenser by a 5-in. pipe, the condenser being reduced in length and a 5-in. flanged tee bolted on one end, making the total face-to-face dimension the same as before. A steam coil, consisting of approximately 22 ft. of $\frac{3}{4}$-in. wrought-steel pipe, was placed in the boiler in such a way that it was entirely below the water level and still left a sufficient disengaging surface for the steam. Steam was supplied to this coil from a high-pressure steam main through a 1-in. pipe. Make-up water for the boiler was taken from a Croton water line through a $\frac{1}{2}$-in. pipe. The bottom of the hot well was also connected to the boiler by a $\frac{3}{4}$-in. line containing a gate and a check valve so that the condensed steam could be returned

directly by gravity to the boiler. This arrangement obviated the necessity of breaking the vacuum and emptying the hot well after each test. A gage glass and a thermometer were installed, the whole apparatus being shown in Fig. 5.

18 To take care of the second item, the vacuum line was increased to 2 in. A ¼-in. connection for a vacuum gage was installed at *E* and a ¾-in. valve opening to atmosphere at *F*. With this arrangement, for any desired opening of the valve *S*, a constant velocity of steam through the condenser could be maintained by regulating the air valve *F* and the valve *K*, so that the steam passing through the valve *S* had a constant drop in pressure. This drop, due to velocity of the steam, was considered to be the difference in pressure as read at *E* and *D*.

19 The subject of air leakage was investigated by closing all valves except *S* and *K* in the vacuum line, when it was found possible to hold a vacuum in the condenser practically equal to that in the large condenser. The valve *S* was then closed and observations were taken as to the rate of fall of the vacuum in the apparatus. It was found that the vacuum would only drop from 28 in. to 27 in. of mercury in 15 min. These air-leakage observations were taken before every series of tests.

20 In order that the condition of the tubes as to cleanliness should not affect the heat temperature, all tubes used for testing were thoroughly cleaned every 10 or 12 tests. A series of tests made with this remodeled apparatus under constant conditions were found to have a maximum variation of not over 10 per cent and an average variation of 3 or 4 per cent. In these tests, the vacuum was varied by regulating the amount of steam admitted to the steam coil through the valve *T*.

21 Tests were run at vacua of 7, 15, 20, 25 and 27 in. of mercury, with circulating water at a temperature of about 40 deg. fahr. and a velocity of 8.6 ft. per sec. on the following kinds of tubes (tests 280 to 528 inclusive):

1 Admiralty
2 Admiralty, oxidized
3 Admiralty, vulcanized inside only
4 Admiralty, vulcanized outside only
5 Admiralty, vulcanized both sides
6 Admiralty, lead lined
7 Admiralty, old tube from condenser
8 Monel
9 Copper
10 Copper, aluminum lined
11 Aluminum bronze
12 Zinc
13 Tin
14 Cupro-nickel
15 Shelby steel
16 Glass

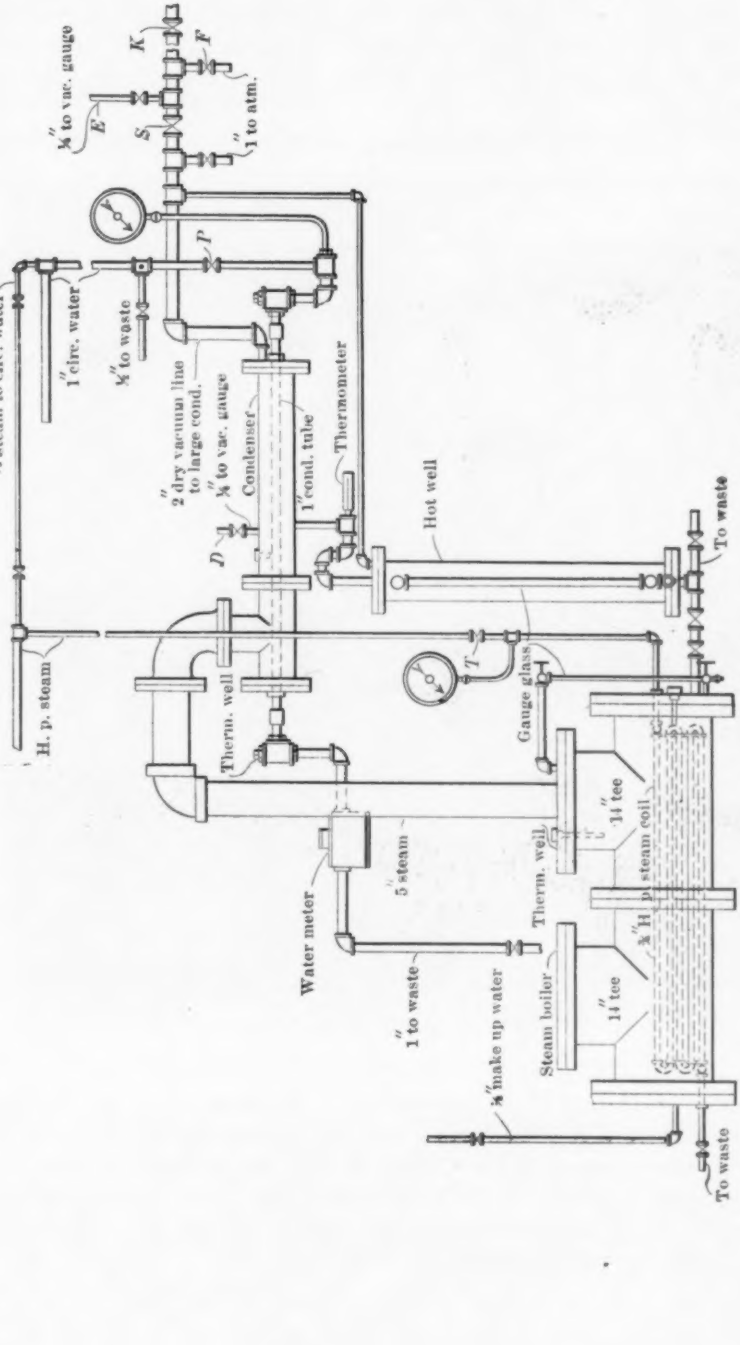


FIG. 5a APPARATUS AS ACTUALLY USED

The tests with the glass tube were difficult to make on account of the thinness and fragility of the tube and the tube was broken before all the desired tests were completed. In all these tests, it was found that the temperature of the steam was constant throughout the apparatus.

22 A series of tests was made on an Admiralty tube with a range in velocity of circulating water of from 1 to 11 ft. per sec. and a

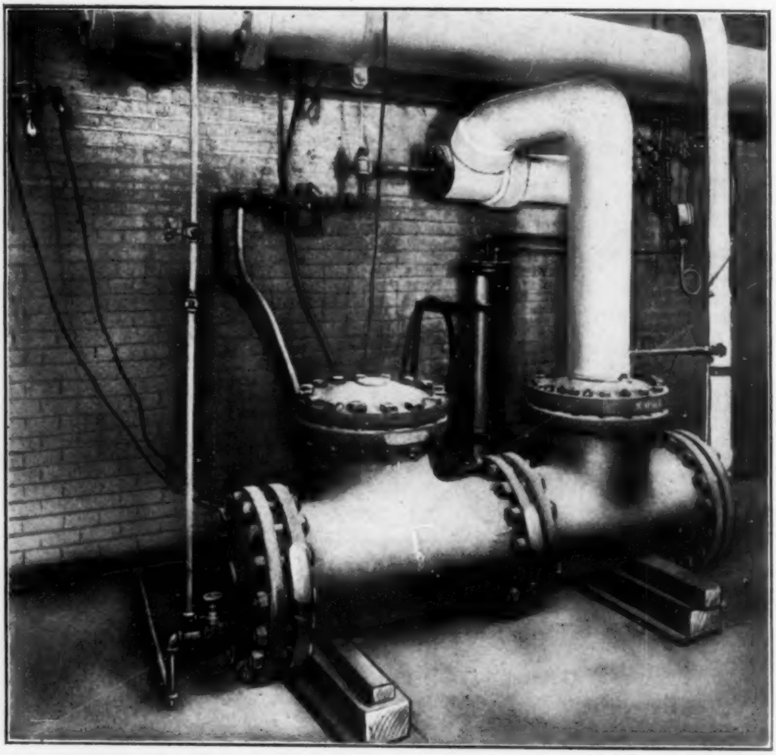


Fig. 5b Apparatus as Actually Used

vacuum of 15 and 27 in. of mercury. In these tests the velocity of the circulating water was varied by regulating the valves at *P* and *V*, the pressure in the condenser tube being always kept above 10 lb. gage. All the above tests were made without changing the temperature of the circulating water, which was about 40 deg. fahr. (tests 529 to 622 inclusive).

23 To vary this temperature, a ½-in. line was installed connecting the high-pressure steam line to the circulating water line as shown in Fig. 5. With this arrangement, it was possible to vary the temperature of the circulating water from 40 to 110 deg. fahr., thus varying the mean temperature difference without altering the other test conditions, and a series of tests was made on an Admiralty tube to determine the variation of heat transfer with changes of mean temperature difference (tests 623 to 727 inclusive).

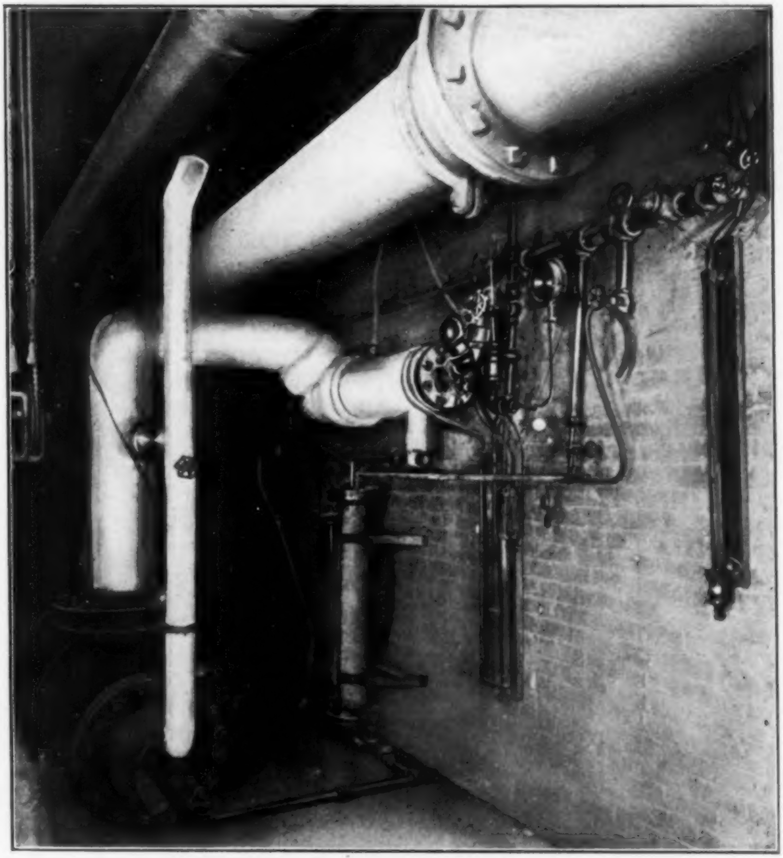


Fig. 5c Apparatus as Actually Used

24 Finally, a series of tests was made on all the various kinds of tubes with circulating water at a temperature of 85 deg. fahr. and velocity of 8.7 ft. per sec. and a vacuum of 27 in. of mercury (tests 728 to 771 inclusive).

VARIATION OF HEAT TRANSFER WITH TEMPERATURE DIFFERENCE

25 After the apparatus had been working some time and had been giving consistent results, a set of approximately 100 tests (623

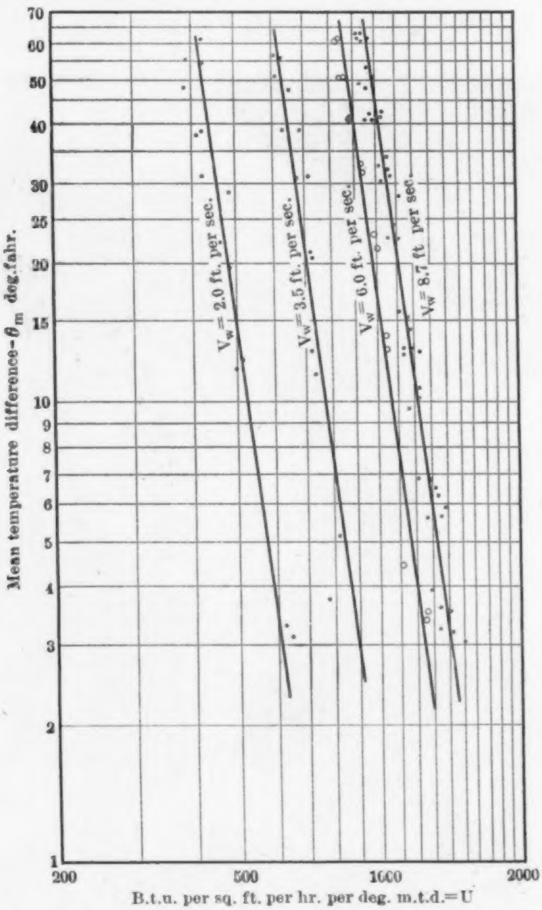


FIG. 6 RELATION OF COEFFICIENT OF HEAT TRANSFER TO TEMPERATURE DIFFERENCE

to 727) was run to determine the possible variation of the heat transmission with the mean temperature difference. The quantities of cooling water were so large that the temperature rise (t_1-t_0) was always small and it was considered that the arithmetical mean of the water temperatures and the steam temperature might be

used without appreciable error in the calculation of the heat transfer. These tests were run at four different velocities, approximately 2, 4, 6, and 8 ft. per sec., the results were plotted on logarithmic paper and a smooth curve drawn through each set of plotted points. These curves were practically straight lines, as shown in Fig. 6, with a slope of about 0.125.

26 The relation may then be stated, $U = \frac{C}{\theta^{\frac{1}{8}}}$. Working from this, an expression may be obtained for the relation between the condensing surface or length of tube S and the temperature rise of the condensing water $(t_1 - t_0)$

$$S = C\left[(t_s - t_0)^{\frac{1}{8}} - (t_s - t_1)^{\frac{1}{8}} \right]$$

and the true mean temperature difference is

$$\theta_m = \left[\frac{\frac{1}{8}\,(t_1 - t_0)}{(t_s - t_0)^{\frac{1}{8}} - (t_s - t_1)^{\frac{1}{8}}} \right]^{\frac{8}{7}}$$

an expression which, in all practical cases, differs very slightly in numerical value from the geometrical mean

$$\theta_m = \frac{(t_1 - t_0)}{\log_e \dfrac{t_s - t_0}{t_s - t_1}}$$

27 The general expression connecting U and θ is then $U = \frac{K}{\theta^n}$, where n may have any positive or negative value excluding 0. The general expression connecting S and $(t_1 - t_0)$ will be

$$S = \frac{C_1}{n}\left[(t_s - t_0)^n - (t_s - t_1)^n \right]$$

and the true mean temperature difference is

$$\theta_m = \left[\frac{n\,(t_1 - t_0)}{(t_s - t_0)^n - (t_s - t_1)^n} \right]^{\frac{1}{1-n}}$$

For the case where $n = 0$ or $U = K$, a constant,

$$S = C \log_e \frac{t_s - t_0}{t - t_1}.$$

and

$$\theta_n = \frac{t_1 - t_0}{\log_e \dfrac{t_s - t_0}{t_s - t_1}}$$

TABLE 1 VALUES OF U, S AND θ FOR VARIOUS ASSUMED VALUES OF N

S = cooling surface in sq. ft.
N = $U\theta$ = total heat transfer per sq. ft. per hr. in B.t.u.
U = heat transfer per sq. ft. per hr. per deg. m.t.d.
θ_m = m.t.d. = mean temperature difference
Q = circulating water per hr. in lb.
K = a constant determined by experiment
t_s = temperature of steam
t_0 = temperature of circulating water at inlet
t_1 = temperature of circulating water at outlet
t = any temperature between t_0 and t_1

1	$N = K$	$U = \dfrac{K}{\theta}$	$S = \dfrac{Q}{K}\left[(t_s - t_o) - (t_s - t)\right]$	$\theta = t_s - \dfrac{t_1 + t_o}{2}$
2	$N = K\theta$	$U = K$	$S = \dfrac{Q}{U} \operatorname{Log}_e \dfrac{t_s - t_o}{t_s - t}$	$\theta = \dfrac{t_1 - t_o}{\operatorname{Log}_e \dfrac{t_s - t_o}{t_s - t_1}}$
3	$N = K\theta^2$	$U = K\theta$	$S = \dfrac{Q}{K}\left[\dfrac{1}{t_s - t} - \dfrac{1}{t_s - t_o}\right]$	$\theta = \sqrt{(t_s - t_o)\ (t_s - t_1)}$
4	$N = K\theta^{\frac{1}{2}}$	$U = \dfrac{K}{\theta^{\frac{1}{2}}}$	$S = \dfrac{2Q}{K}\left[(t_s - t_o)^{\frac{1}{2}} - (t_s - t)^{\frac{1}{2}}\right]$	$\theta = \left[\dfrac{\frac{1}{2}(t_1 - t_o)}{(t_s - t_o)^{\frac{1}{2}} - (t_s - t_1^{\frac{1}{2}})}\right]^2$
5	$N = K\theta^{\frac{7}{8}}$	$U = \dfrac{K}{\theta^{\frac{1}{8}}}$	$S = \dfrac{8Q}{K}\left[(t_s - t_o)^{\frac{1}{8}} - (t_s - t)^{\frac{1}{8}}\right]$	$\theta = \left[\dfrac{\frac{1}{8}(t_1 - t_o)}{(t_s - t_o)^{\frac{1}{8}} - (t_s - t_1)^{\frac{1}{8}}}\right]^{\frac{8}{7}}$
6	$N = \dfrac{K}{\theta^{n-1}}$	$U = \dfrac{K}{\theta^n}$	$S = \dfrac{Q}{Kn}\left[(t_s - t_o)^n - (t_s - t)^n\right]$	$\theta = \left[\dfrac{n(t_1 - t_o)}{(t_s - t_o)^n - (t_s - t_1)^n}\right]^{\frac{1}{1-n}}$

In Table 1 these values for U, S, θ_m and N (the total quantity of heat transferred) are tabulated and the curves of temperature rise and values of θ_m are plotted in Fig. 7 for certain steam and water temperatures.

28 Only two investigators, so far as I have been able to determine, have attempted experimentally to verify the law of the rise of temperature of condensing water in its passage through the condensing tube.

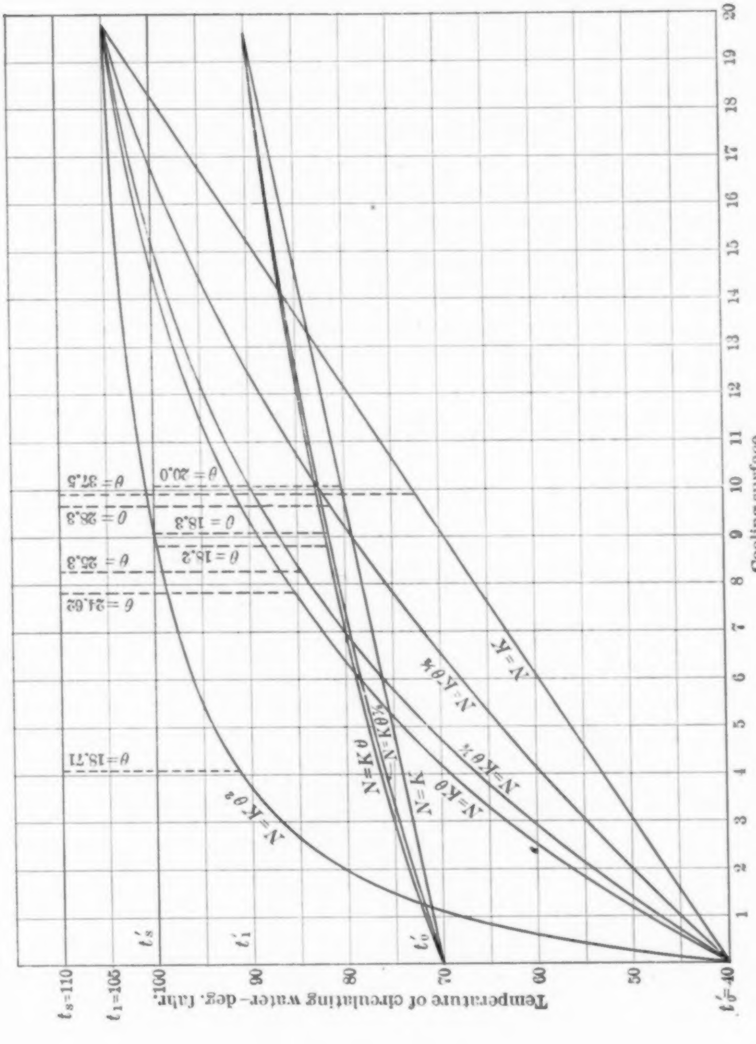


FIG. 7 CURVES OF TEMPERATURE RISE UNDER CERTAIN ASSUMPTIONS

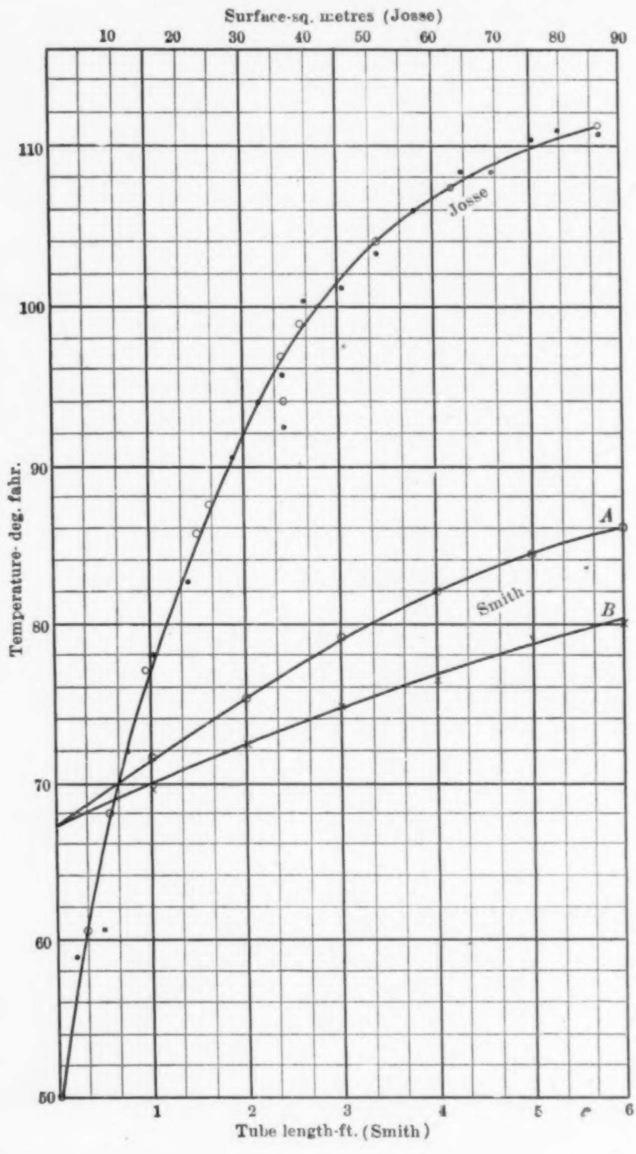


FIG. 8 EXPERIMENTAL CURVES OF TEMPERATURE RISE

J. Alex. Smith[1] experimented with a tube 6 ft. long, and Professor Josse[2] used a surface condenser approximately 86 sq. m. of surface. Neither experimenter gives his actual numbers but shows his results in a curve. Smith gives a second curve showing the deviation of his experimental numbers from the geometrical series which best represents his results. These curves are shown in Fig. 8 and the variation from the geometrical curve may be clearly seen. It is unfortunate that further accurate experiments have not been made on this particular phase of the subject, but none of these results are inconsistent with the conclusions arrived at from the author's experiments. In fact, the variations between the geometrical curve found by Josse and Smith and the writer's experiments are smaller than the variations of the actual points and the theoretical points plotted in Fig. 8.

VARIATION OF HEAT TRANSFER WITH VELOCITY OF WATER

29 A series of practically 100 tests was run to determine the variation of heat transferred to the velocity of the circulating water (tests 529 to 622 inclusive). These tests were run at various velocities from 1 to 11 ft. per sec. and the results are plotted in Fig. 9. These tests were run at two different vacua, 15 in. and 27 in. approximately, and the figure shows how closely the heat transmission varies with the square root of the water velocity. The third curve in Fig. 9 is a curve of total heat transmitted and apparently varies according to the same law.

30 The earlier investigators found somewhat different results. Josse and Foster have both taken advantage of the researches of Professor Ser of the School of Arts and Manufactures of Paris. Josse gives his results in a set of curves, while Foster gives a set of numbers. I have not been able to find the original figures. The numbers given by Foster and scaled from Josse's curves in metric measures are as follows:

[1] London Engineering, Mar. 23, 1906.
[2] Zeitschrift des Vereins Deutscher Ingenieure, Feb. 27, 1909.

TABLE 2 SER'S NUMBER FOR U

V_w m.	U cal. Foster	U cal. Josse	V_w ft.	U B.t.u.	$\sqrt[3]{V_w}$	C	$\sqrt{V_w}$	C
0.10	1400	1400	0.328	287	0.69	416	0.573	501
0.20	2300	2230	0.656	464	0.868	534	0.811	572
0.30	2550	2550	0.984	522	0.994	525	0.992	526
0.40	2710	2710	1.31	555	1.093	507	1.143	485
0.50	2860	2860	1.64	586	1.18	496	1.28	458
0.60	3020	3010	1.967	617	1.252	493	1.402	440
0.70	3180	3180	2.295	652	1.318	495	1.515	430
0.80	3330	3330	2.622	682	1.378	495	1.62	421
0.90	3480	3480	2.95	712	1.435	496	1.717	415
1.00	3640	3640	3.28	745	1.485	501	1.81	412
1.10	3800	3800	3.61	778	1.532	507	1.9	409

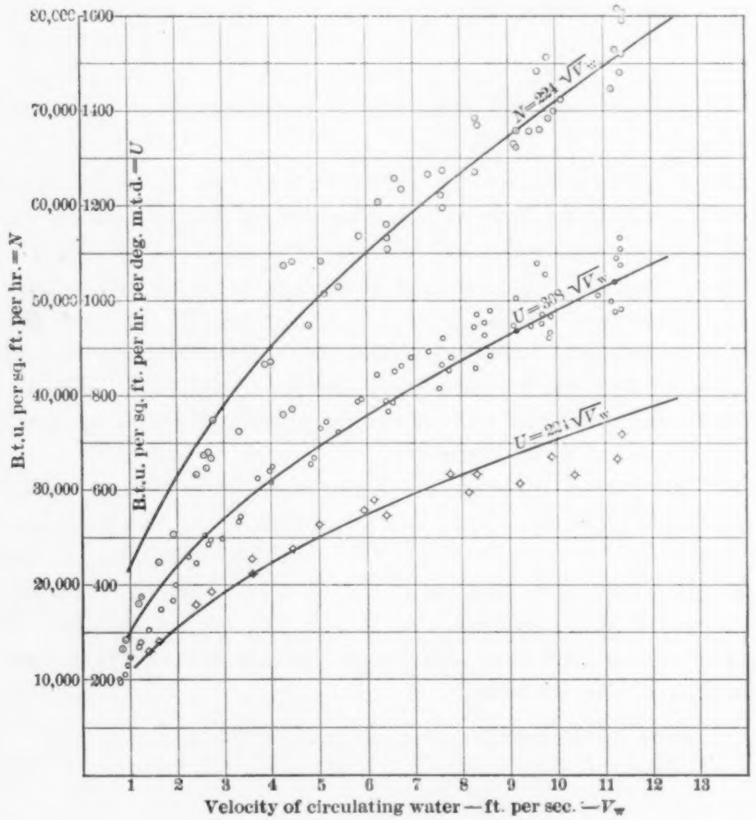


FIG. 9 VARIATION OF HEAT TRANSMISSION WITH WATER VELOCITY (ORROK)

From these numbers, Ser's experiments may be best represented by $U = 490\sqrt[3]{V_w}$ or, if the transmission corresponding to 0.328 ft. per sec. be neglected, $U = 508\sqrt[3]{V_w}$, the variations from the square root curve being much greater.

31 Josse has also published a curve giving the results of Joule's experiments which follows very closely the expression $U = 239\sqrt[3]{V_w}$. Joule's actual numbers are available and have been recalculated. The low-vacuum tests, up to 2.5 in. of mercury absolute pressure, follow very nearly the above figure, but the mean of all tests within condenser conditions is more nearly stated by the expression $U = 315\sqrt[3]{V_w}$.

32 The work of these two experimenters is widely known and has had nearly universal acceptance until within a very few years, when a number of authorities have claimed that the fact might be better expressed by the formula $U = C\sqrt{V_w}$. In support of this view, Hagemann's experiments were cited and Josse's own experiments on small-size condensers appear to agree well with this expression. Stanton deduced from his experiments at Owens College that U was directly proportional to the velocity, but his numbers have never been published.

33 The curves in Fig. 10 show the relation between heat transfer and circulating-water velocity for all of the experimenters whose work has been recalculated in connection with this paper. There may be some doubt as to the constant in any one case, but all the results from the curves are merely the true average of the experimental figures. It is probable that the critical velocity was exceeded in all cases.

VARIATION OF HEAT TRANSFER WITH VELOCITY OF STEAM

34 That the velocity of the steam across the tube surface has an effect on the transmission has been asserted by a number of authorities. Hausbrand and Ser have considered that the heat transmission was proportional to the square root of the steam speed. Jordan maintains that the transmission is proportional to the mass flow of the steam. Most of the other investigators have neglected this. In the experiments, we have been unable to detect any effect on the heat transmission which might be charged to the velocity of the steam approaching the tube surface.

35 Let us consider a condenser consisting of a single tube, through which the cooling water is flowing, surrounded by an atmosphere of steam. Condensation will take place at the outer surface of the tube and the steam will rush in to the tube from all sides. Meanwhile, the space surrounding the tube will attain a constant pressure

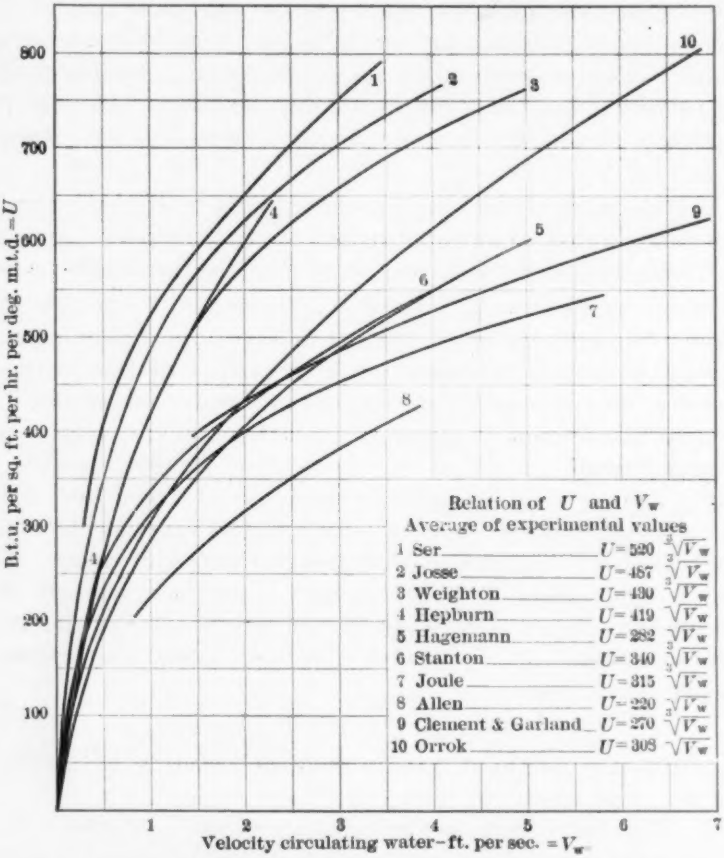


FIG. 10 VARIATION OF HEAT TRANSMISSION WITH WATER VELOCITY (VARIOUS AUTHORITIES)

due to the regular influx of steam into the condenser and its condensation on the tube. This constant pressure will determine the temperature of the steam and if there is no air leakage the temperature will be that due to the saturated vapor of water at the constant pres-

sure. It has been determined experimentally that the temperature and pressure remain sensibly constant throughout the condenser, except for an exceedingly minute space in the neighborhood of the tube surface.

36 There is then a constant flow normal to the surface of the tube besides such residual velocity as may be in the steam after its passage

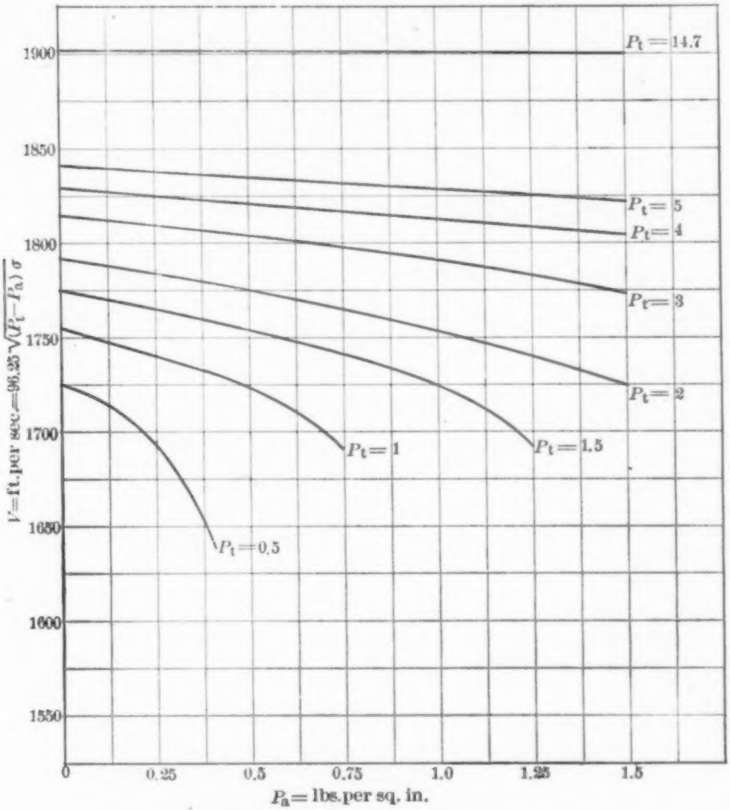


FIG. 11 VARIATION OF STEAM VELOCITY WITH AIR

through the exhaust pipe. This residual velocity in practice is usually from 200 to 600 ft. per sec. and in turbine installations may be as high as 800 ft. per sec. In direction, it follows the axis of the eduction nozzle until deflected by the tubes, sides of the condenser or baffle plates and constantly loses velocity until, at the further end of the steam travel, this velocity is entirely lost. The

component of this residual velocity longitudinally to the tube is of no value in bringing a particle of steam to the condensing surface; neither is the component of this velocity normal to the tube surface, for its action is balanced by carrying away the steam on the opposite side of the tube. Its only action then is to distribute the steam among the tubes.

37 When a particle of steam comes in contact with the surface of the tube, it is immediately condensed and contracts enormously in volume. At atmospheric pressure the volume of water is approximately $\frac{1}{1660}$ of the steam volume. At 28 in. of vacuum, or 1 lb. abs., the contraction is about $\frac{1}{21,500}$, and at 29.,5 in., or $\frac{1}{4}$ lb. abs. 77,000 cu. ft. of steam condenses to 1 cu. ft. of water. The vacuum thus created induces a flow of steam normal to the steam surface, the velocity of which, neglecting friction, can easily be calculated for various conditions by means of the formula $V = \sqrt{2gh}$. Transforming this formula we get $V = 96.25 \sqrt{(P_t - P_a)\ \sigma}$, where P_t = vacuum pressure (lb. abs.), P_a = partial pressure due to air in the condenser, and σ = specific volume of steam at pressure $(P_t - P_a)$.

38 The velocity with which the steam particles strike the tube surface is apparently independent of the distance they travel before striking and is reasonably independent of the vacuum. The velocity varies from about 1750 ft. per sec. at 1 lb. abs. to about 1900 ft. per sec. at 14.7 lb. abs. or atmosphere. These values of V are shown in Fig. 11 and the effect of a small quantity of air in the condenser on the velocity of flow of the steam is shown to be very small.

THE EFFECT OF AIR UPON HEAT TRANSMISSION

39 During the early portion of these tests it was impossible even to approximate air-free steam, so that consistent transfer results could not be obtained. With the changing of the apparatus to a closed cycle, it was possible to keep the air down to a rather small quantity and the results obtained were much more consistent. It is probable in these cases that the partial air pressure never exceeded $\frac{1}{2}$ in. and in most cases was below this point. By close attention to all possible sources of air leaks in the final tests run

from, say, No. 400 on, it is probable that the partial air pressure never exceeded $\frac{1}{4}$ in. and was sometimes much less than this.

40 The best experiments on the effect of air that I have been able to find were described by James Alexander Smith in a paper read before the Victorian Institute of Engineers on December 6, 1905, which was reprinted in London Engineering, March 23, 1906. An abstract of this paper will be found in Appendix No. 2. His results show that a partial pressure of air amounting to $\frac{1}{10}$ in. will reduce the heat transmission 25 per cent; $\frac{1}{4}$ in. of air will reduce it 40 per cent; and $\frac{3}{8}$ in. partial air pressure will reduce the heat transfer about 50 per cent. It is much to be regretted that Mr. Smith did not give his numbers, but the curves are sufficiently clear for use.

CONCLUSIONS

41 *a* The heat transferred from condensing steam surrounding a metallic tube to cold water flowing through the tube is proportional to the seven-eighths power of the mean temperature difference of the water and steam temperatures. This is equivalent to the statement that the coefficient of heat transfer, U, is inversely proportional to the eighth root of the mean temperature difference.

b The coefficient of heat transmission, U, is approximately proportional to the square root of the velocity of the cooling water.

c The coefficient U is independent of the vacuum and of the velocity of the steam among the tubes or in the condenser passages. It may be proportional to the square root of the velocity normal to the tubes, but in all common cases this velocity does not vary more than a tenth part.

d The effect of air on the heat transferred is very marked indeed, particularly at high vacua, and most of this air is due to leakage through the walls and joints of the apparatus. Working from Smith's curves and certain picked tests, where the volume of air could be calculated, the effect of the presence of air in reducing the value of U is as follows:

$$U = c\left(\frac{P_s}{P_t}\right)^5$$

where P_s is the partial pressure due to the steam and P_s is the total steam and air pressure.

e Taking the heat transfer of the copper tube as 1.00, under similar conditions the transfer for other materials is approximately as follows: copper, 1.00, Admiralty, 0.98, aluminum lined, 0.97, Admiralty oxidized (black), 0.92, aluminum bronze, 0.87, cupro-nickel, 0.80, tin, 0.79, Admiralty lead-lined, 0.79, zinc, 0.75, Monel metal, 0.74, Shelby steel, 0.63, old Admiralty (badly corroded), 0.55, Admiralty vulcanized inside, 0.47, glass, 0.25, Admiralty vulcanized both sides, 0.17. This coefficient (due to the material of the tube) will be designated by μ. Corrosion, oxidation, vulcanizing, pitting, etc., have also a marked effect in reducing the transfer. This reduction, best shown by the Admiralty tube which gave $\mu = 0.55$, may reduce the transfer at least 50 per cent.

f The foregoing conclusions may be expressed mathematically as follows:

$$U = K \frac{C \rho^{5} \mu \sqrt{V_w}}{\theta^{\frac{1}{8}}}$$

where C = the cleanliness coefficient varying from 1.00 to 0.5

μ = the material coefficient varying from 1.00 to 0.17

ρ = the steam richness ratio, $\frac{P_s}{P_t}$ varying from 1.00 to 0.

V_w = the water velocity in ft. per sec.

θ = the mean temperature difference

K = a constant, probably about 630

The effect of the length of tube, or rather length of water travel, has not been considered and the design of the condenser must be such that there is a free steam passage to every tube.

g This expression for U is cumbersome to use and for modern turbine condenser work certain conditions may be taken as well settled. The guaranteed vacuum is usually 28 in. The entrance circulating water is usually 70 deg. and a 20 deg. temperature rise is considered economical. Under these conditions $\theta = 18.3$ and $6^{\frac{1}{8}} = 1.44$.

θ calculated on the geometrical curve is 18.2. For these cases it will be nearly as accurate and much simpler to calculate θ by the logarithmic method, neglecting θ in the denominator and using 435 or $\frac{630}{1.44}$ for K^1. The expression will then be $U = K^1\, C\, P^5\, \mu \sqrt{V_w}$.

h The above equation agrees well with the results of a number of tests on full size condensers under varying conditions. There appears to have been no attempt to determine the amount of air handled by the air pump in these cases, but the amounts of air indicated by the formula are such as agree with the pressures and temperature taken. The measurement of the dry pump discharge has been undertaken and the author hopes to have more information on this point in the future.

42 In conclusion, the author wishes to acknowledge the efficient aid rendered him in conducting the experiments and calculating the results by his assistants P. E. Reynolds and H. R. Callaway.

APPENDIX NO. 1

LIST OF SYMBOLS USED AND TABLES RELATING TO TESTS MADE BY THE AUTHOR

V_w = water velocity, ft. per sec.
V_s = steam velocity, ft. per sec.
U = heat transmission coefficient, B.t.u. per sq. ft. per deg. difference per hr.
θ = temperature difference, deg. fahr.
θ_m = mean temperature difference, deg. fahr.
t_0 = temperature of inlet water
t_1 = temperature of overflow water
t = any temperature
t_s = temperature due to pressure of saturated steam
$\left.\begin{matrix} K \\ C \end{matrix}\right\}$ = constants
N = total heat transmitted per hour, B.t.u.
h = head, ft.
g = 32.2
σ = specific volume of steam at pressure $(P_t - P_a)$
P_t = vacuum pressure, lb. abs.
P_a = partial air pressure in condesnser, lb. abs.
P_s = partial steam pressure in condenser, lb abs.
μ = material coefficient
ρ = steam richness ratio, $\left(\frac{P_s}{P_t}\right)$
S = cooling surface, sq. ft.
Q = circulating water per hour, lb.
W = steam condensed per hour, lb.
R = $\frac{Q}{W}$
p = absolute pressure in condenser, in. of mercury

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES*

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Admiralty Tube, 1 in. Outside Diameter, 18 B.W.G.											
280	8510	53.2	160	8.43	2.67	110.5	36.04	42.52	6.48	71.22	774
281	8530	89.8	95	8.44	5.27	135.9	35.44	46.14	10.7	95.07	960
282	8670	134.2	64.5	8.56	9.82	160.9	35.36	51.04	15.68	117.7	1153
283	8660	166.2	52	8.55	15.09	178.8	36.5	55.5	19.0	132.8	1240
284	8550	211	40.5	8.44	32.0	215.5	37.3	61.2	23.9	166.3	1228
285	8570	157	54.7	8.47	14.99	178.4	36.07	54.20	18.13	133.2	1166
286	8550	125.5	68	8.44	9.99	161.4	37.73	52.58	14.85	116.2	1091
287	8625	83.5	103.3	8.53	4.95	132.1	38.30	48.15	9.85	88.9	955
288	8570	52.3	164	8.47	2.95	112.0	36.70	42.98	6.28	72.2	755
289	8570	180.0	47.7	8.47	22.82	197.9	39.15	59.63	20.48	148.5	1181
290	8550	178	48.1	8.44	22.92	198.2	37.75	58.05	20.3	150.3	1154
291	8625	55.2	156	8.53	2.79	116.2	35.8	42.38	6.58	77.09	737
292	8650	82.1	105	8.55	4.89	133.8	35.48	45.13	9.65	93.44	893
293	8570	124.2	69	8.47	9.90	161.6	35.43	50.10	14.68	118.9	1057
294	8625	152	57	8.53	14.90	178.8	36.40	53.73	17.43	133.8	1123
295	8525	174	49	8.42	22.52	197.6	36.38	56.38	20.00	151.3	1126
296	8750	55	159	8.64	3.06	117.6	37.53	43.98	6.45	76.8	734
297	8950	79.9	112	8.85	5.11	135.7	37.95	47.03	9.08	93.2	872
298	8900	120	74	8.80	9.91	161.4	37.00	50.65	13.65	117.5	1033
299	8825	149.5	59	8.72	14.98	179.2	36.45	53.20	16.75	134.4	1100
300	8825	174	50.7	8.72	22.56	198.0	36.93	56.23	19.30	151.4	1125
301	8875	120	73.8	8.77	9.86	161.3	36.65	50.33	13.68	117.8	1030
302	8370	59.7	140	8.27	3.28	118.8	37.3	44.6	7.3	77.85	785
303	8570	86.7	99	8.47	5.46	137.3	37.23	47.5	10.27	94.93	928
304	8525	125	68.2	8.42	10.63	164.3	36.1	50.73	14.63	120.9	1030
305	8525	148	57.7	8.42	15.53	180.4	36.17	53.32	17.15	135.7	1077
306	8475	167	50.6	8.37	23.13	198.8	36.92	56.27	19.35	152.2	1078
307	8420	65.2	129	8.32	4.26	129.3	36.63	44.53	7.9	88.7	751
308	8440	76.5	110.3	8.35	5.69	136.2	39.03	48.25	9.22	92.6	840
309	8600	112.5	76.3	8.50	10.15	160.7	39.08	52.35	13.27	115.0	991
310	8550	137	62.4	8.44	15.17	178.3	38.78	54.63	15.85	131.6	1030
311	8650	162	53.4	8.55	22.56	197.5	38.53	56.85	18.32	149.8	1058
312	8600	168	51.0	8.50	29.90	212.1	38.83	57.83	19.0	163.8	998
313	8925	54.5	164	8.82	3.04	115.6	39.33	45.6	6.27	73.1	765
315	8600	76.0	113.3	8.50	5.14	135.1	39.28	48.25	8.97	91.3	845
316	8600	109	78.7	8.50	10.02	161.3	39.0	51.83	12.83	115.9	952
317	8690	136	63.7	8.60	15.02	178.7	38.08	53.6	15.52	132.9	1015
318	8690	158	55.0	8.60	22.67	197.7	40.68	58.48	17.80	148.1	1043
319	8300	48.8	170	8.20	3.05	117.3	39.42	45.45	6.03	74.9	668
320	8300	74.5	111.5	8.20	5.03	135.0	38.4	47.5	9.1	92.05	821
321	8370	106	79.0	8.27	10.05	161.9	39.9	52.73	12.83	115.6	930

* Tests 220 to 336 inclusive made without removing tube from apparatus. When removed tube was found to be covered with an accumulation of the black paint which was used on gaskets and joints to stop air leakage.

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.
MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of $\frac{\text{Water}}{\text{Steam}}$ to $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Admiralty Tube, 1 in. Outside Diameter, 18 B.W.G.											
322	8550	130	65.7	8.44	15.12	179.5	40.3	55.35	15.05	131.7	977
323	8440	151	55.9	8.35	22.65	197.5	38.15	55.65	17.5	150.6	982
324	8690	157	54.7	8.60	30.0	212.1	38.73	56.45	17.72	164.5	937
325	8750	172	50.8	8.64	34.06	218.8	38.83	57.83	19.0	170.5	975
326	8750	179	48.8	8.64	41.8	229.4	38.3	57.95	19.65	181.4	948
327	8650	191	45.2	8.55	60.9	250.2	37.98	58.88	20.9	202.1	895
328	8600	159	54.1	8.50	29.5	211.2	38.45	56.35	17.9	164.8	935
329	8650	166	51.9	8.55	35.5	220.9	39.02	57.6	18.58	172.6	932
330	8600	172	49.9	8.50	42.7	230.5	38.88	58.08	19.20	182.0	907
331	8550	187	45.6	8.44	61.4	250.4	40.2	60.88	20.68	199.9	885
332	9125	161	56.5	9.02	30.0	212.7	37.95	55.1	17.15	166.2	942
333	9025	174	51.7	8.92	35.6	221.6	38.0	56.65	18.65	174.0	967
334	8900	182	49.0	8.80	42.7	230.3	37.92	57.5	19.58	182.6	955
335	8850	197	44.9	8.75	61.5	251.5	38.55	59.6	21.05	202.4	920
336*	8300	104	80.0	8.20	9.9	161.8	37.5	50.13	12.63	118.0	888
337†	8700	118	73.5	8.60	9.9	161.5	38.18	51.95	13.77	116.4	1028
338	8900	67.3	132	8.80	4.06	126.0	40.6	48.33	7.73	81.5	845
339	8840	78.7	111	8.74	5.02	133.8	40.1	49.3	9.20	89.1	913
340	8770	116	75.5	8.66	9.9	161.6	38.33	51.73	13.4	116.6	1010
341	8770	138	63.7	8.66	14.6	179.1	38.7	54.23	15.53	132.6	1027
342	8620	149	57.8	8.51	22.5	197.8	39.8	56.7	16.9	149.6	975
343	8650	133	64.8	8.55	22.5	197.6	39.4	54.48	15.08	150.7	867
344	8770	115	76.4	8.66	14.9	178.8	39.03	52.0	12.97	133.3	853
345	8650	94.0	92.0	8.55	9.9	160.9	38.85	49.83	10.98	116.6	823
346	8620	65.2	132	8.51	5.3	135.8	39.08	46.8	7.72	92.9	718
347	8890	69.5	128	8.77	3.01	115.5	41.83	49.83	8.00	69.7	1020
New Admiralty Tube Installed, Tube Being Cleaned Every 8 or 10 Tests											
348	8700	91.3	95.2	8.59	5.02	133.8	40.58	51.25	10.67	87.9	1055
349	8620	122	70.5	8.51	9.9	161.5	39.85	54.20	14.35	114.5	1080
350	8700	160	54.3	8.59	14.8	178.7	37.73	55.93	18.2	131.9	1200
351	8700	186	46.7	8.59	22.5	197.9	38.23	60.2	21.97	148.7	1285
352	8470	67.7	125	8.36	3.00	115.3	39.45	47.65	8.20	71.7	970
353	8620	90.4	95.4	8.51	5.01	133.7	39.28	49.93	10.65	89.1	1032
354	8470	120	70.4	8.36	9.90	160.1	37.98	52.33	14.35	114.9	1057
355	8470	152	55.8	8.36	14.8	178.8	40.2	57.9	17.7	120.7	1155
356	8540	188	45.5	8.44	22.5	197.6	44.98	66.48	21.5	141.8	1295
357	8470	179	47.4	8.36	22.5	197.5	45.18	65.8	20.62	142.0	1230
358	8540	149	57.3	8.44	14.8	178.5	42.85	60.10	17.25	127.0	1157
359	8650	123	70.3	8.55	10.0	160.8	41.90	56.25	14.35	111.7	1112
360	8650	87.7	98.7	8.55	5.02	133.7	41.55	51.85	10.30	87.0	1025
361‡	8650	68.5	126	8.55	3.09	116.3	42.5	50.63	8.13	69.7	1010
362	8810	90.8	97	8.70	5.11	135.1	42.58	53.05	10.47	87.3	1055

* Test 336 made before cleaning tube.
† Test 337 made after cleaning tube.
‡ Tests 361 to 369 inclusive made with dry vacuum line wide open.

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
New Admiralty Tube Installed, Tube Being Cleaned Every 8 or 10 Tests											
363	8650	129	67	8.55	10.09	161.7	41.58	56.5	14.92	112.7	1145
364	8650	162	53.6	8.55	15.19	179.6	38.58	57.03	18.45	131.8	1210
365	8620	195	44.3	8.51	22.79	198.2	40.8	62.9	22.1	146.4	1297
366	8810	222	39.7	8.70	22.77	198.1	42.0	66.63	24.63	143.8	1505
367	8770	169	52	8.66	15.07	178.9	41.68	60.7	19.02	127.7	1307
368	8770	135	65.1	8.66	10.09	161.9	45.4	60.78	15.38	108.8	1237
369	8810	94.2	93.6	8.70	5.09	134.6	45.48	56.33	10.85	83.7	1142
370	8770	69.0	127	8.66	3.11	117.0	44.68	52.73	8.05	68.3	1032
371	8500	44.7	190	8.40	2.28	105.4	46.35	51.8	5.45	56.3	822
372	8440	57.3	147	8.32	3.15	116.3	42.03	49.03	7.00	70.8	832
373	8540	69.3	123	8.44	5.22	136.1	45.2	53.45	8.25	86.8	812
374	8390	91.3	91.8	8.29	10.2	162.2	45.9	56.8	10.9	110.9	825
Admiralty Tube, 1 in. Outside Diameter, 18 B.W.G.											
375	8620	111	77.5	8.51	15.22	179.5	44.53	57.28	12.75	128.6	847
376	8500	126	67.3	8.40	23.0	198.5	46.05	60.6	14.55	145.2	852
378	8280	51.6	160	8.17	2.63	110.7	49.03	55.48	6.45	58.4	912
379	8470	74.2	114	8.36	5.00	132.8	48.58	57.48	8.90	79.8	942
380	8570	106	81	8.47	9.78	160.1	43.80	56.28	12.48	110.1	973
381	8540	125	68	8.44	14.78	178.4	44.60	59.15	14.55	126.5	982
382	8540	161	53	8.44	22.33	196.9	43.62	62.13	18.50	144.0	1098
383	8620	122	70.4	8.51	9.58	159.6	44.25	58.60	14.35	108.2	1142
384	9150	63	145	9.03	2.80	114.1	47.8	54.90	7.1	62.7	1035
385	9040	75.2	120	8.92	3.85	125.4	48.5	56.98	8.48	72.7	1055
386	9120	62.8	145	9.00	2.80	113.8	47.55	54.63	7.08	62.7	1030
387	8840	75.5	117	8.74	3.82	124.8	46.53	55.13	8.7	74.0	1040
388	8960	63.0	142	8.85	2.80	113.6	45.5	52.7	7.2	64.5	1000
389	8730	74.0	118	8.62	3.82	124.7	46.65	55.33	8.68	73.7	1030
390	8925	85.8	104	8.81	4.77	133.5	46.5	56.28	9.78	82.1	1063
391	8925	49.5	180	8.81	2.07	103.9	52.3	58.03	5.73	48.7	1052
392	9000	64.7	139	8.89	2.93	115.0	47.88	55.25	7.37	63.4	1045
393	9040	81.4	111	8.92	4.90	133.0	45.18	54.3	9.12	83.3	990
394	8840	81.8	107	8.74	4.93	133.1	52.98	62.45	9.47	75.4	1110
395	9000	123	73.3	8.89	9.91	161.0	52.4	66.18	13.78	101.7	1220
396	8925	149	59.7	8.81	14.96	179.0	51.42	68.1	16.68	110.2	1248
Copper Tube, 1 in. Outside Diameter, 16 B.W.G.											
397	8730	53.5	163	8.65	2.98	115.6	46.98	53.28	6.30	65.5	840
398	8840	71.2	124	8.77	4.95	133.6	46.95	55.18	8.23	82.5	872
399	8890	70.5	126	8.80	4.95	133.3	42.73	50.83	8.10	86.5	832
400	8770	91.2	96.2	8.70	9.9	161.0	45.25	55.75	10.5	111.5	827
401	9000	57.3	157	8.92	3.26	118.1	48.6	55.13	6.53	66.2	888
402	8810	81.5	108	8.73	5.23	135.5	46.32	56.75	9.43	84.0	990
403	8890	119	75.0	8.80	10.23	162.1	48.85	62.2	13.35	106.6	1110
404	8970	134	67.0	8.83	15.26	179.8	45.8	60.53	14.73	126.6	1060
405	8925	152	58.8	8.80	22.97	198.3	49.1	65.75	16.65	140.9	1053

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Copper Tube, 1 in. Outside Diameter, 16 B.W.G.											
406	9040	134	67.3	8.92	15.2	179.5	46.45	61.15	14.7	125.7	1057
407	8810	114	77.3	8.70	10.15	162.0	44.75	57.7	12.95	110.8	1030
408	8925	83.5	107	8.81	5.2	135.0	45.55	55.08	9.53	84.7	1005
409	8810	63.4	139	8.70	3.2	117.5	49.18	56.53	7.35	64.6	1003
Aluminum Bronze Tube, 1 in. Outside Diameter, 18 B.W.G.											
410	8650	66.5	130	8.55	3.29	118.1	44.68	52.58	7.90	69.5	984
411	9040	83.5	108	8.92	5.17	135.1	49.38	58.8	9.42	81.0	1047
412	8970	108	83.2	8.85	10.22	162.0	48.50	60.53	12.03	107.5	1002
413	8925	119	75.0	8.81	15.19	179.2	44.1	57.3	13.2	128.5	918
414	8925	138	64.7	8.81	22.85	198.0	44.58	59.83	15.25	145.8	932
415	9000	142	63.5	8.89	22.87	198.1	43.48	58.80	15.42	147.0	945
416	8810	115	76.6	8.70	15.17	179.3	45.68	58.60	12.92	127.2	895
417	8770	108	81.5	8.66	10.14	161.7	47.28	59.68	12.4	108.2	1005
418	8770	76.2	115	8.66	5.09	135.4	47.63	56.43	8.80	83.4	925
419	8810	63.8	138	8.70	3.14	116.6	40.2	47.63	7.43	72.7	900
Copper Tube, 1 in. Outside Diameter, 16 B.W.G.											
420	8890	61.2	145	8.80	3.13	116.5	42.35	49.45	7.1	70.6	893
421	8700	78.4	111	8.60	5.08	134.1	42.35	51.55	9.20	87.1	918
422	8650	108	79.8	8.98	10.18	162.0	41.78	54.30	12.52	114.0	950
423	8730	127	68.5	9.05	15.07	178.9	41.90	56.33	14.43	129.7	973
424	8650	146	59.0	8.98	22.82	197.9	42.63	59.23	16.60	147.0	977
Cupro-Nickel, 1 in. Outside Diameter, 18 B.W.G.											
425	8840	57.3	154	8.74	3.09	116.0	42.48	49.15	6.67	69.2	853
426	9120	74	123	9.00	4.87	132.9	42.45	50.73	8.28	80.3	875
427	9120	101	90.6	9.00	9.81	160.6	42.00	53.15	11.15	113.0	898
428	8890	120	74	8.77	14.87	178.7	41.13	54.48	13.35	130.9	907
429	9080	145	62.6	8.96	22.56	197.4	40.63	56.28	15.65	148.9	953
431	8970	57.5	156	8.85	3.04	115.8	40.38	46.95	6.58	72.1	820
432	8840	72.4	122	8.74	4.94	133.6	41.35	49.7	8.35	88.1	838
433	8840	98.7	89.7	8.74	10.03	161.1	41.68	52.93	11.25	113.8	875
434	9000	117	76.8	8.89	14.98	178.9	48.6	61.48	12.88	123.9	935
435	8810	139	63.3	8.70	22.89	198.0	46.35	61.83	15.48	143.9	948
Aluminum-Lined Copper Tube, 1 in. Outside Diameter, 0.06 in. Thick											
436	8840	61.7	143	9.18	3.07	115.1	43.08	50.23	7.15	68.9	918
437	8925	82.6	108	9.25	5.07	133.9	42.2	51.63	9.43	87.0	967
438	9000	116	77.7	9.34	10.13	161.7	42.18	55.18	13.0	113.0	1033
439	9080	137	66.2	9.41	15.1	178.8	42.98	57.93	14.95	128.3	1058
440	9040	162	55.8	9.36	22.95	198.1	42.58	60.1	17.52	146.8	1078
441	8970	168	53.4	9.30	22.95	198.1	41.5	59.82	18.32	147.4	1110
442	9040	144	62.7	9.36	15.05	178.1	40.88	56.65	15.77	129.3	1098
443	8970	120	74.7	9.30	10.02	162.4	41.98	55.38	13.4	113.7	1055
444	9040	82.8	109	9.36	4.96	133.3	42.30	51.63	9.33	86.3	975
445	8890	59.7	149	9.21	3.09	115.9	42.05	48.95	6.90	70.4	887

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_W	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
				Monel Tube, 1 in. Outside Diameter, 18 B.W.G.							
446	8925	57.1	156	8.81	3.51	119.6	40.58	47.13	6.55	75.7	773
447	8810	68.2	129	8.70	5.01	133.3	40.80	48.68	7.88	88.6	783
448	8970	91.0	98.5	8.85	10.08	161.5	40.80	51.03	10.23	115.6	794
449	8840	107	82.5	8.74	14.96	178.5	40.50	52.5	12.0	132.0	805
450	8970	128	70.0	8.85	22.98	198.1	40.15	54.13	13.98	151.0	830
451	8810	126	70.0	8.70	23.01	198.1	40.0	54.0	14.0	151.1	817
452	9000	107	83.8	8.89	15.01	178.1	40.8	52.6	11.8	131.4	807
453	8890	89	100	8.77	9.95	160.5	41.13	51.2	10.07	114.3	792
454	8890	66.3	134	8.77	5.00	133.1	41.55	49.13	7.58	87.8	768
455	9040	55.4	163	8.92	3.42	118.8	40.95	47.25	6.30	74.7	762
				Admiralty Tube, Oxidized, 1 in. Outside Diameter, 18 B.W.G.							
459	8840	129	68.7	8.74	15.04	178.9	44.98	59.38	14.4	126.7	1005
460	8840	151	58.5	8.74	22.94	198.2	45.25	61.98	16.73	144.6	1023
461	8810	149	59.0	8.70	22.95	198.5	43.98	60.55	16.57	146.2	998
462	9080	127	71.5	8.96	15.05	178.8	43.8	57.63	13.83	128.1	980
463	9040	103	88.0	8.92	10.02	161.4	46.33	57.8	11.48	109.3	958
464	8970	74.7	12.0	8.85	5.05	134.2	48.38	56.88	8.50	81.6	934
465	8890	63.0	141	8.77	3.67	123.2	47.13	54.38	7.25	72.9	885
466	9040	78.5	115	8.92	5.37	136.0	47.03	55.9	8.87	84.5	948
467	8810	108	81.3	8.70	10.39	162.6	45.55	57.85	12.3	110.9	977
				Zinc Tube, 1 in. Outside Diameter, 18 B.W.G.							
469	9000	53.0	170	8.89	3.52	120.4	44.85	50.88	6.03	72.5	738
470	8925	65.0	137	8.81	5.49	137.1	44.1	51.5	7.40	89.3	740
471	8970	84.6	106	8.85	10.34	162.6	45.12	54.58	9.45	112.8	751
472	8840	100	88	8.74	15.32	179.8	44.15	55.4	11.25	130.0	765
473	8970	121	74	8.85	23.38	199.5	43.55	56.78	13.23	149.3	793
474	8925	46.2	193	8.81	3.36	118.8	49.5	54.8	5.30	66.7	712
475	8925	63.2	141	8.81	5.35	136.5	43.62	50.82	7.20	89.3	720
476	9080	82.5	110	8.96	10.35	162.4	46.33	55.45	9.12	111.5	740
477	9040	96.0	94.3	8.92	15.20	179.5	49.00	59.5	10.5	125.2	757
478	9040	115	78.3	8.92	23.07	198.5	49.10	61.6	12.5	143.1	787
				Aluminum-Bronze Tube, 1 in. Outside Diameter, 18 B.W.G.							
479	8925	62.3	143	8.81	3.53	120.7	42.85	50.02	7.17	74.3	852
480	8925	75.6	118	8.81	5.38	136.6	42.4	51.02	8.62	89.9	857
481	8730	95.2	91.8	8.62	10.28	162.5	45.72	56.8	11.08	111.2	870
482	8890	112	79.5	8.77	15.28	179.9	52.28	64.73	12.45	121.4	910
483	9000	133	67.3	8.89	23.19	198.2	47.98	62.5	14.52	142.9	915
484	8840	65.0	136	8.74	4.03	126.5	45.10	52.82	7.52	77.6	857
485	9040	73.5	123	8.92	5.08	134.8	43.85	52.13	8.28	86.8	860
486	8730	95.0	92.0	8.62	9.95	160.75	44.55	55.55	11.0	110.7	868
487	8970	117	76.2	8.85	15.13	179.1	48.02	61.00	12.98	124.6	938
488	8890	133	67.1	8.77	23.03	198.5	49.32	64.12	14.8	141.8	927
489	9000	95.0	94.8	8.89	10.15	161.6	51.3	61.95	10.65	105.0	912

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Admiralty Tube, Lead Lined, 1 in. Outside Diameter, 0.088 in. Thick											
491	9000	55.2	163	10.54	4.02	125.6	49.98	56.25	6.27	72.5	778
492	8890	62.6	142	10.50	5.12	134.5	50.68	57.85	7.17	80.2	795
493	8770	87.7	100	10.36	10.01	161.1	51.35	61.4	10.05	104.7	845
494	8840	108	81.5	10.45	14.99	179.0	50.23	62.4	12.17	122.7	875
495	8810	129	68.3	10.41	22.84	198.0	49.73	64.08	14.35	141.1	895
496	8840	130	68.1	10.46	22.77	198.1	47.7	62.08	14.38	143.2	887
497	8650	110	78.5	10.23	14.94	178.9	45.63	58.25	12.62	127.0	860
498	8620	92.8	93.0	10.18	9.99	161.0	44.68	55.55	10.87	110.9	852
499	8620	69.0	125	10.18	5.86	139.1	44.9	52.98	8.08	90.1	773
Shelby Steel Tube, 1 in. Outside Diameter, 18 B.W.G.											
500	8970	55.0	163	8.85	3.49	120.0	45.88	52.15	6.27	71.0	788
501	8925	65.0	137	8.81	5.01	132.9	45.38	52.8	7.42	83.8	790
502	8840	82.6	107	8.74	10.03	161.1	46.35	55.83	9.47	110.0	762
503	8970	99.5	90.2	8.85	15.0	179.0	45.93	56.9	10.97	127.6	775
504	8970	111	80.5	8.85	22.80	198.1	49.88	62.03	12.15	142.1	765
505	8970	108	83.2	8.85	22.77	198.1	55.28	67.05	11.77	136.9	770
506	9040	94.5	95.7	8.92	14.89	178.4	51.95	62.28	10.33	121.3	770
Shelby Steel Tube with Coating of Rust											
507	8925	44.8	199	8.81	3.53	121.1	52.65	57.8	5.15	65.9	695
508	8840	55.5	159	8.74	5.23	135.3	49.3	55.68	6.38	82.8	682
509	8730	71.0	123	8.62	10.26	162.5	44.63	52.78	8.15	112.8	630
Tin Tube, 1 in. Outside Diameter, 0.055 in. Thick											
510	8840	47.2	187	9.12	3.59	120.8	57.25	62.73	5.48	60.8	797
511	8650	64.0	135	8.92	5.09	133.8	44.9	52.4	7.50	85.1	764
512	8890	87.0	102	9.15	10.17	161.4	44.4	54.2	9.80	112.1	778
513	8770	96.3	91.2	9.04	15.14	179.0	52.33	63.18	10.85	121.2	785
514	8570	113	75.5	8.84	23.17	198.6	51.7	64.53	12.83	140.5	783
515	8650	113	76.6	8.92	22.94	198.4	51.23	63.88	12.65	140.8	778
516	8970	96.6	93.0	9.24	15.12	178.8	52.7	63.35	10.65	120.8	790
517	8840	81.0	109	9.12	10.10	161.0	52.88	62.18	9.30	103.4	793
518	8700	60.8	143	8.98	5.10	133.5	50.95	58.05	7.10	79.0	781
519	8890	53.5	166	9.15	4.10	125.6	51.93	58.10	6.17	70.6	775
Old Admiralty Tube Taken from Large Condenser, 1 in. Outside Diameter, 18 B.W.G.											
520	8730	48.2	181	8.62	4.49	129.0	45.0	50.63	5.63	81.2	606
521	8620	69.0	125	8.51	9.87	159.8	53.2	61.28	8.08	102.6	675
522	8620	84.5	102	8.51	14.87	177.9	52.58	62.25	9.67	121.4	686
523	8650	103	84	8.55	22.87	197.9	50.23	61.88	11.65	141.8	710
524	8650	105	82.5	8.55	22.77	197.1	46.48	58.35	11.87	144.6	710
525	8730	43.0	203	8.62	3.51	121.1	52.68	57.73	5.05	65.9	667
526	8700	53.2	163	8.58	5.23	135.4	53.23	59.45	6.22	79.1	683
527	8840	73.0	121	8.74	10.28	162.3	54.2	62.5	8.30	103.9	704
528	8840	86.6	102	8.74	15.20	179.3	55.03	64.75	9.72	119.4	717

TABLE 4 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES

MADE TO DETERMINE EFFECT OF CIRCULATING WATER VELOCITY ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	t_1-t_0	θ_m	U
Old Admiralty Tube Taken from Large Condenser, 1 In. Outside Diameter, 18 B.W.G.											
529	11252	53.8	209	11.3	5.25	134.4	50.6	55.48	4.88	82.4	668
530	10530	51.6	204	10.4	5.28	135.5	49.75	54.75	5.00	83.2	634
531	9340	49.1	190	9.24	5.23	134.3	49.6	54.98	5.38	81.8	615
532	8240	47.3	174	8.15	5.23	134.1	50.05	55.93	5.88	81.1	595
533	6490	42.5	152	6.42	5.20	133.8	50.3	57.03	6.73	80.1	545
534	6030	42.7	141	5.97	5.25	134.1	52.3	59.55	7.25	78.2	558
535	4440	37.0	120	4.49	5.23	133.8	48.05	56.58	8.53	81.0	473
536	3640	33.0	110	3.60	5.25	133.9	50.23	59.53	9.3	79.0	428
537	1670	21.4	78	1.65	5.23	134.0	50.25	63.33	13.08	77.2	283
538	1440	19.7	73.1	1.43	5.12	134.8	52.5	66.45	13.95	75.3	267
539	2425	27.1	89.7	2.41	5.02	134.3	51.88	63.25	11.38	76.7	360
540	2737	28.2	97.0	2.72	5.12	134.4	54.43	64.95	10.52	74.7	388
541	3640	33.1	110	3.60	5.10	134.8	55.43	64.7	9.28	74.7	452
542	5085	39.1	130	5.03	5.04	134.3	54.48	62.35	7.87	75.9	527
543	6255	45.0	139	6.19	5.14	134.6	51.35	58.7	7.35	79.6	578
544	7855	47.8	164	7.77	5.10	134.3	54.1	60.33	6.23	77.1	635
545	8425	50.1	168	8.33	5.10	134.8	50.7	56.78	6.08	81.1	633
546	10000	53.8	186	9.91	5.02	134.3	49.48	54.98	5.50	82.1	670
547	11495	57.2	201	11.4	5.07	134.1	50.0	55.08	5.08	81.6	716
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.											
548	11325	69.8	162	11.2	4.06	126.3	50.9	57.25	6.35	72.2	1000
549	9980	67.4	148	9.88	4.11	126.3	51.38	58.3	6.91	71.5	967
550	9560	66.3	144	9.47	4.08	126.1	50.7	57.8	7.10	71.8	945
551	9225	65.8	140	9.13	4.06	126.3	50.5	57.83	7.33	72.1	938
552	7700	58.3	132	7.62	4.11	126.6	53.55	61.3	7.75	69.2	864
553	6525	54.8	119	6.46	4.11	126.4	50.58	59.2	8.62	71.5	788
554	5500	50.0	110	5.44	4.11	127.0	51.43	60.73	9.30	70.9	722
555	4060	42.2	96.4	4.02	4.13	127.1	51.90	62.55	10.65	69.9	618
556	2693	31.7	85.0	2.66	4.13	126.6	54.73	66.78	12.05	65.8	492
557	1212	17.5	69.5	1.20	4.13	127.0	53.88	68.63	14.75	65.7	273
558	11515	67.3	156	11.4	3.95	124.9	50.98	57.58	6.60	70.6	1076
559	10160	69.0	147	10.1	4.10	126.1	52.05	59.05	7.00	70.5	1008
560	7700	62.1	124	7.63	4.08	126.3	53.03	61.28	8.25	69.1	920
561	9260	64.7	143	9.17	4.03	125.4	56.5	63.68	7.18	65.8	1005
562	6830	59.8	114	6.76	4.00	125.1	49.08	58.1	9.02	71.5	862
563	5120	52.4	97.8	5.07	4.08	126.4	47.53	58.03	10.50	73.6	732
564	3980	42.0	94.7	3.94	4.13	126.7	53.9	64.73	10.83	67.4	640
565	2675	32.7	81.8	2.65	4.15	126.8	54.3	66.85	12.55	66.2	507
566	1250	18.1	69.1	1.24	4.15	127.0	53.98	68.83	14.85	65.6	283
567	11380	74.2	153	11.26	4.12	126.5	49.58	56.30	6.72	73.6	1040
568	9795	69.0	142	9.70	4.02	125.4	50.25	57.48	7.23	71.5	950
569	9225	65.3	141	9.12	4.02	125.0	50.38	57.68	7.30	71.0	947
570	7400	61.7	120	7.32	4.12	126.0	50.43	58.95	8.52	70.3	895
571	6340	59.2	107	6.27	4.11	126.5	49.83	59.38	9.55	71.9	842
572	4332	52.5	82.4	4.28	4.16	126.9	49.80	62.25	12.45	70.9	760
573	4475	52.5	85.2	4.43	4.11	126.0	49.8	61.83	12.03	70.2	769
574	11520	78.3	147	11.40	4.28	127.5	52.78	59.78	7.00	71.2	1132

TABLE 4. TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE TO DETERMINE EFFECT OF CIRCULATING WATER VELOCITY ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury.	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	t_1-t_0	θ_m	U
				Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.							
575	9750	72.7	134	9.65	4.18	126.4	53.63	61.28	7.65	68.8	1080
576	8770	68.1	130	8.67	4.10	125.6	50.35	58.33	7.98	71.3	980
577	8620	66.6	130	8.52	4.20	126.4	51.7	59.63	7.93	70.7	963
578	7055	59.9	118	6.98	4.13	126.0	52.25	60.95	8.70	69.4	883
579	4060	43.3	93.6	4.01	4.13	126.1	51.45	62.4	10.95	68.7	647
580	5885	55.2	107	5.82	4.08	125.5	49.15	58.78	9.63	71.5	792
581	2690	32.9	81.7	2.67	4.23	126.6	49.68	62.25	12.57	69.6	487
582	872	12.9	67.7	0.86	4.26	127.4	51.85	67.03	15.18	68.0	195
583	11270	79.4	142	11.3	4.10	125.5	47.25	54.48	7.23	74.6	1090
584	11340	78.0	146	11.4	4.00	125.9	50.45	57.5	7.05	71.9	1110
585	9905	73.1	135	9.8	4.03	126.0	50.45	58.03	7.58	71.8	1056
586	8425	67.1	125	8.33	4.00	125.3	50.5	58.68	8.18	70.7	973
587	8390	67.6	124	8.30	3.97	124.8	47.13	55.4	8.27	73.5	943
588	6680	61.1	109	6.61	4.05	126.5	48.1	57.5	9.40	73.7	852
589	4060	44.1	92	4.01	4.07	126.0	50.63	61.8	11.17	69.8	648
590	5195	49.1	106	5.14	3.93	124.5	51.7	61.4	9.70	68.0	741
591	2767	32.6	84.8	2.74	4.10	126.6	53.15	65.25	12.10	67.4	497
592	2463	30.7	80.3	2.44	4.20	128.1	54.6	67.38	12.78	67.1	470
593	1743	22.9	76.2	1.65	4.12	126.5	55.68	69.15	13.47	64.1	350
594	986	13.8	71.5	0.98	4.15	126.3	57.25	71.6	14.35	61.9	229
595	11340	72.1	157	11.4	4.09	126.6	47.6	54.12	6.52	75.7	980
596	9985	68.0	147	9.88	4.09	126.8	47.7	54.68	6.98	75.6	922
597	8460	61.8	137	8.37	3.97	125.1	47.02	54.5	7.48	74.3	852
598	7665	59.2	129	7.59	4.12	127.1	48.55	56.48	7.93	74.6	818
599	6520	52.9	123	6.46	3.99	125.5	49.3	57.65	8.35	72.0	767
600	4890	45.7	107	4.84	4.07	126.4	49.48	59.08	9.60	72.1	652
601	8035	89.5	90.0	3.00	4.09	126.5	51.1	62.55	11.45	69.6	498
602	3375	35.2	96.0	3.34	3.99	125.1	51.82	62.52	10.7	67.9	531
603	1972	24.5	80.5	1.95	4.07	126.6	51.82	64.65	12.83	68.3	370
604	949	13.9	68.0	0.94	4.15	127.0	50.6	65.7	15.1	68.8	208
605	11075	139	79.5	10.95	18.0	187.0	47.08	59.45	12.37	133.7	1010
606	9835	133	73.9	9.74	17.98	186.8	46.68	59.98	13.3	133.5	968
607	8615	127	68.0	8.52	17.95	186.8	46.72	61.18	14.46	132.9	926
608	7895	121	65.4	7.82	18.05	187.1	46.8	61.83	15.03	133.8	876
609	5960	107	55.6	5.89	17.97	186.8	46.95	64.63	17.68	131.0	794
610	3830	82.6	46.4	3.79	17.92	186.7	47.38	68.58	21.2	128.7	623
611	2010	52.4	38.4	1.99	18.05	187.0	47.98	73.55	25.57	126.2	401
612	2313	59.8	38.7	2.29	18.0	186.8	48.0	73.38	25.38	126.1	459
613	873	25.3	34.5	0.86	17.95	187.0	49.10	77.53	28.43	123.7	198
614	11380	135	84.3	11.28	17.82	186.4	47.68	59.32	11.66	132.9	985
615	9985	127	78.6	9.87	17.99	186.9	48.18	60.68	12.5	132.5	929
616	8730	120	73.0	8.64	17.99	186.6	48.50	61.95	13.45	131.4	881
617	7855	115	68.4	7.77	17.82	186.0	48.25	62.62	14.38	130.6	854
618	6605	105	63.2	6.53	17.89	186.3	49.55	65.10	15.55	128.9	787
619	4970	88.8	56.0	4.92	17.97	186.6	48.10	65.68	17.58	129.7	665
620	3412	71.6	47.6	3.38	18.01	186.6	48.05	68.7	20.65	128.2	542
621	1479	39.6	37.4	1.46	18.19	187.3	48.70	75.03	26.33	125.4	306
622	2463	58.4	42.2	2.44	17.99	186.6	48.18	71.43	23.25	126.8	446

TABLE 5 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES

MADE TO DETERMINE EFFECT OF VARIATIONS OF MEAN TEMPERATURE DIFFERENCE ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
				Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.							
623	9000	59.2	163	8.91	2.65	111.6	46.98	53.35	6.37	60.9	940
624	9040	54.6	165	8.94	2.70	111.5	47.53	53.8	6.27	60.8	930
625	8840	44.3	199	8.75	2.70	111.3	61.05	66.25	5.20	47.6	967
626	8840	37.5	236	8.75	2.65	111.0	69.95	74.35	4.40	38.8	1000
627	8970	30.3	296	8.86	2.73	111.9	81.85	85.35	3.50	28.3	1108
628	9040	14.3	593	8.94	2.75	112.1	98.53	100.28	1.75	12.7	1233
638	8890	56.4	157	8.79	2.90	114.6	47.90	54.48	6.58	63.4	920
639	8840	44.4	199	8.75	2.90	114.1	62.83	68.03	5.20	48.7	945
640	8890	40.0	222	8.70	2.93	114.3	70.08	74.78	4.70	41.9	995
641	8970	34.4	261	8.86	2.93	115.1	79.58	83.55	3.97	33.5	1062
642	8810	24.8	354	8.72	2.95	114.4	90.13	93.10	2.92	22.8	1127
643	8810	17.0	518	8.72	2.95	116.0	99.4	101.4	2.00	15.6	1130
644	8620	8.50	1015	8.52	2.95	114.5	107.16	108.18	1.02	6.80	1290
645	8810	14.7	599	8.72	2.87	113.9	99.72	101.45	1.73	13.3	1145
646	8810	23.0	384	8.72	2.87	113.9	90.85	93.55	2.70	21.7	1095
647	8730	30.6	285	8.63	2.90	114.4	82.60	86.23	3.63	30.0	1055
648	8730	39.4	222	8.63	2.85	113.5	69.88	74.55	4.67	41.3	985
649	9000	57.1	158	8.91	3.00	115.4	48.58	55.15	6.57	63.5	930
650	9000	50.2	179	8.91	3.05	116.0	59.8	65.58	5.78	63.3	975
651	9000	41.0	220	8.91	2.97	114.5	70.53	75.25	4.72	41.6	1018
652	8925	32.1	278	8.82	3.00	114.6	81.35	85.08	3.73	31.4	1060
653	8810	25.0	353	8.72	3.03	115.1	90.00	92.93	2.93	23.7	1088
654	8925	17.2	518	8.82	3.05	117.4	100.98	102.98	2.00	15.4	1158
655	8890	4.30	2070	8.79	3.04	115.5	111.88	112.38	0.50	3.30	1342
656	8925	4.40	2030	8.82	3.04	115.0	111.13	111.64	0.51	3.60	1263
657	8925	15.9	560	8.82	3.02	115.0	100.33	102.18	1.85	13.8	1193
658	8925	56.5	158	8.82	2.98	113.8	49.8	56.35	6.55	60.7	963
659	8810	48.5	182	8.72	3.03	114.5	61.18	66.88	5.70	50.5	993
660	8970	42.2	212	8.86	3.05	114.8	69.83	74.75	4.92	42.5	1036
661	8840	32.2	274	8.75	3.13	115.1	81.40	85.13	3.73	31.8	1050
662	8840	24.1	366	8.75	3.13	115.0	90.62	93.45	2.83	23.0	1088
663	8810	14.7	598	8.72	3.13	115.3	101.35	103.08	1.73	13.1	1163
664	8730	4.90	1786	8.63	3.14	115.3	111.07	111.65	0.58	3.90	1295
665	8970	5.02	1786	8.86	3.14	115.1	111.10	111.68	0.58	3.70	1403
666	8840	15.2	581	8.75	3.14	115.3	101.34	103.12	1.78	13.1	1200
667	9080	24.8	366	8.98	3.09	115.4	90.75	93.68	2.83	23.1	1113
668	8730	32.6	267	8.63	3.09	115.0	80.35	84.23	3.88	32.7	1035
669	8810	40.2	219	8.72	3.02	114.8	71.12	75.85	4.73	41.3	1008
670	8810	48.3	182	8.72	3.05	115.0	61.38	67.05	5.68	50.8	984
671	8970	7.90	1138	8.86	2.86	114.5	107.27	108.18	0.91	6.80	1200
672	8810	8.40	1057	8.72	2.88	114.4	107.27	108.25	0.98	6.60	1305
673	9000	4.80	1881	8.91	2.90	114.9	110.90	111.45	0.55	3.70	1335
674	8810	4.40	1981	8.72	2.92	114.7	111.28	111.82	0.54	3.15	1510

TABLE 5 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE TO DETERMINE EFFECT OF VARIATIONS OF MEAN TEMPERATURE DIFFERENCE ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_i	$t_1 - t_0$	θ_m	U
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.											
675	8970	6.70	1345	8.86	2.92	114.0	108.51	109.28	0.77	5.40	1275
676	8810	10.8	815	8.72	2.93	114.6	104.38	105.65	1.27	9.60	1165
678	8840	8.00	1101	8.75	3.05	114.7	107.99	108.93	0.94	6.20	1342
679	8890	12.1	735	8.79	3.02	113.6	102.79	104.2	1.41	10.2	1228
680	8730	12.6	690	8.64	3.10	115.3	103.88	105.38	1.50	10.7	1225
681	8970	7.50	1190	8.86	3.10	115.1	109.06	109.93	0.87	5.60	1367
682	8770	4.30	2030	8.68	3.15	115.4	111.94	112.45	0.51	3.20	1395
683	8890	7.90	1125	8.80	3.15	115.1	108.86	109.78	0.92	5.80	1405
686	6185	4.80	1294	6.12	3.10	114.6	109.80	110.6	0.80	4.40	1123
687	6030	13.9	435	5.97	3.10	114.3	99.45	101.83	2.38	13.7	1047
688	5995	21.1	284	5.93	3.04	113.4	89.83	93.48	3.65	21.7	1007
689	5995	28.6	209	5.93	3.12	115.0	81.10	86.05	4.95	31.4	945
690	5955	35.6	167	5.90	3.10	114.3	69.78	75.98	6.20	41.4	892
691	6185	42.4	146	6.12	3.10	114.2	60.73	67.83	7.10	49.9	868
692	6220	47.9	130	6.16	3.10	115.0	49.70	57.68	7 98	61.3	812
693	6300	48.5	130	6.24	3.12	114.5	49.53	57.5	7.97	61.0	823
694	6220	41.5	150	6.16	2.95	114.3	60.80	67.7	6.90	50.0	858
695	6185	36.2	171	6.12	2.95	115 3	70.25	76.3	6.05	42.0	891
696	6262	29.7	211	6.20	2.95	115 5	80.18	85.10	4.92	32.9	935
697	6340	22.0	288	6.28	2.97	114.5	89.95	93.55	3.60	22.7	1005
698	6370	13.2	481	6.31	2.95	114.5	100.38	102.53	2.15	13.0	1055
699	6185	4.30	1480	6.12	2.95	114.5	110.78	111.48	0.70	3.40	1272
700	3640	3.90	1262	3.61	2.95	114.5	110.33	111.15	0.82	3.80	786
701	3718	9.20	403	3.68	2.93	113.3	99.08	101.65	2.57	12.9	741
702	3415	10.3	233	3.38	3.08	114.3	91.33	95.78	4.45	20.7	733
703	3792	21.6	176	3.76	3.03	113.5	79.65	85.55	5.90	30.9	723
704	3718	26.5	140	3.68	3.08	114.1	71.05	78.45	7.40	39.3	700
705	3718	30.2	123	3.68	3.08	113.6	62.35	70.78	8.43	47.0	665
706	3680	33.9	108	3.64	3.08	114.0	53.73	63.28	9.55	55.5	632
707	3680	34.0	108	3.64	3.08	114.0	52.93	62.50	9.57	56.1	627
708	3562	29.8	120	3.53	3.02	113.5	59.80	68.45	8.65	49.4	625
709	3562	25.0	142	3.53	3.02	113.8	70.90	78.18	7.28	39.3	660
710	3562	20.6	173	3.53	3.03	114.0	80.25	86.23	5.98	30.8	693
711	3562	14.8	241	3.53	3.06	114.1	90.85	95.15	4.30	21.1	722
712	3562	8.40	423	3.53	2.96	113.3	100.30	102.75	2.45	11.8	740
713	3600	4.00	901	3.57	3.08	115.4	109.75	110.9	1.15	5.10	812
714	2028	21.0	97.0	2.01	2.81	112.4	51.78	62.48	10.7	55.3	392
715	1859	17.6	105	1.83	2.91	113.8	61.48	71.30	9.82	47.6	383
716	1859	14.9	124	1.83	2.86	113.0	71.08	79.4	8.32	37.7	410
717	1820	12.4	146	1.80	2.93	113.5	79.35	86.42	7.07	30.6	420
718	1915	8.80	217	1.90	2.86	112.6	90.50	95.28	4.78	19.7	478

TABLE 5 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE TO DETERMINE EFFECT OF VARIATIONS OF MEAN TEMPERATURE DIFFERENCE ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.											
719	2160	5.70	376	2 14	2.96	113.8	100.48	103.23	2.75	11.9	500
720	2160	1.90	1114	2.14	2.93	113.8	110.30	111.23	0.93	3.10	650
721	2085	1.90	1068	2.07	2.86	112.8	109.18	110.15	0.97	3.2	632
722	2102	6.10	348	2.09	2.89	112.9	99.15	102.13	2.98	12.3	510
723	1952	10.1	193	1.93	2.96	113.9	88.67	94.05	5.38	22.5	467
724	2122	14.1	151	2.10	2.91	113.1	80.58	87.43	6.85	29.1	500
725	2141	22.1	96.8	2.12	2.89	113.6	63.5	64.2	10.7	54.7	418
726	2045	18.9	108	2.03	2.89	113.5	61.85	71.4	9.55	46.9	433
727	1895	15.8	120	1.87	2.99	114.6	71.03	79.68	8.65	39.2	418

TABLE 6 TESTS OF HEAT TRANSFER

	Test Number	Circulating Water Used Per Hour, Lb.	Steam Condensed Per Hour, Lb.
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.	728	8925	32.6
	729	8730	33.5
Copper Tube, 1 In. Outside Diameter, 16 B.W.G.	730	9080	33.6
	731	9150	33.1
Cupro-Nickel Tube, 1 In. Outside Diameter, 18 B.W.G.	732	8810	26.1
	733	9000	26.9
Old Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.	733A	8970	19.7
	734	8770	19.1
Aluminum-Bronze Tube, 1 In. Outside Diameter, 18 B.W.G.	735	9040	30.4
	736	8970	30.2
Monel Tube, 1 In. Outside Diameter, 18 B.W.G.	737	9000	24.5
	738	9040	25.3
Aluminum-Lined Tube, 1 In. Outside Diameter, 18 B.W.G.	739	8840	33.5
	740	9080	33.9
Shelby Steel Tube, 1 In. Outside Diameter, 18 B.W.G.	741	9040	22.8
	742	8840	22.0
Admiralty Lead-Lined, 1 In. Outside Diameter, 0.088 In. Thick	743	8650	27.6
	744	8810	27.3
Admiralty-Oxidized, 1 In. Outside Diameter, 18 B.W.G.	745	8890	30.8
	746	9040	32.0
Zinc Tube, 1 In. Outside Diameter, 18 B.W.G.	747	8925	26.0
	748	8970	25.7
Tin Tube, 1 In. Outside Diameter, 0.055 In. Thick	749	8840	27.7
	750	8970	27.2
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.	751	9080	105
	752	8970	101
	753	8890	93.1
	754	8925	82.7
	755	9120	70.5
	756	8770	62.0
	757	8890	104
	758	8620	95.7
	759	8840	89.0
	760	8770	80.5
	761	8730	70.5
	762	8890	59.8
Copper Tube, 1 In. Outside Diameter, 16 B.W.G.	763	8925	51.8
	764	9040	71.1
	765	9080	99.4
	766	8970	117
	767	9000	138
Admiralty, Vulc. Inside, 1 In. Outside Diameter, 18 B.W.G.	768	8730	177
	769	8730	186
Admiralty, Vulc. Both Sides, 1 In. Outside Diameter, 18 B.W.G.	770	8770	6.4
	771	9040	6.6

THROUGH CONDENSER TUBES

Ratio of Water to Steam	Velocity of Water in Tube, Ft. Per. Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
274	8.83	2.81	114.4	85.75	89.53	3.78	26.8	1257
260	8.62	2.86	115.7	85.50	89.48	3.98	28.2	1232
270	9.38	2.93	114.7	85.40	89.23	3.83	27.4	1267
276	9.42	2.91	114.3	84.78	88.53	3.75	27.6	1243
337	8.71	2.99	114.9	86.03	89.1	3.07	27.3	988
334	8.90	2.93	114.1	85.38	88.48	3.10	27.2	1024
456	8.87	2.96	114.8	84.58	86.85	2.27	29.1	703
460	8.67	2.96	114.6	85.45	87.70	2.25	28.0	705
298	8.94	3.12	116.0	85.45	88.93	3.48	28.8	1090
298	8.87	3.05	114.9	84.62	88.10	3.48	28.5	1092
368	8.90	2.99	113.8	85.18	88.00	2.82	27.2	932
357	8.94	2.99	114.5	84.92	87.82	2.90	28.1	932
264	8.99	2.96	115.3	84.90	88.83	3.93	28.4	1223
268	9.21	2.96	115.0	85.28	89.15	3.87	27.8	1262
395	8.94	3.07	115.6	84.88	87.50	2.62	29.4	805
401	8.75	2.99	115.1	85.60	88.18	2.58	28.2	808
309	10.00	3.01	115.1	85.10	88.45	3.35	28.3	1023
322	10.20	2.99	114.9	85.52	88.75	3.23	27.8	1022
288	8.79	3.07	115.5	85.38	88.98	3.60	28.1	1136
282	8.94	3.04	115.0	85.15	88.82	3.67	28.0	1183
343	8.83	3.07	115.6	85.98	89.00	3.02	28.1	958
348	8.87	3.07	115.0	85.48	88.45	2.97	28.0	948
318	8.94	3.14	115.9	86.00	89.25	3.25	28.3	1015
329	9.07	3.07	115.0	85.48	88.63	3.15	27.9	1009
86.6	8.98	9.70	161.3	53.30	64.88	11.58	102.2	1027
89.0	8.87	9.68	160.3	53.55	64.83	11.28	101.1	1000
95.5	8.79	9.68	160.0	63.98	74.48	10.5	90.8	1027
108	8.83	9.57	159.3	77.93	87.2	9.27	76.6	1078
129.4	9.02	9.72	160.5	93.00	100.75	7.75	63.6	1108
141.2	8.67	9.75	160.6	101.80	108.9	7.10	55.2	1127
85.4	8.79	9.84	161.3	55.33	67.08	11.75	100.1	1040
90.0	8.52	9.78	161.1	62.50	73.65	11.15	93.0	1033
99.4	8.75	9.85	161.0	72.60	82.7	10.1	83.3	1070
109	8.68	9.71	160.3	81.25	90.45	9.2	74.4	1083
124	8.64	9.73	160.0	92.93	101.03	8.10	63.0	1120
149	8.79	9.75	160.5	106.50	113.25	6.75	50.7	1182
172	9.25	3.02	114.9	56.68	62.7	6.02	54.2	992
127	9.36	4.97	134.0	56.63	64.68	8.05	73.3	1005
91.4	9.37	9.82	160.7	56.85	67.83	10.98	98.3	1015
76.4	9.30	14.79	178.1	56.50	69.45	12.95	115.1	1007
65.1	9.34	22.52	197.0	56.65	71.65	15.00	132.8	1017
49.2	8.65	3.00	117.8	85.95	88.05	2.10	30.8	596
47.0	8.65	3.00	117.2	84.45	86.65	2.20	31.6	607
1380	8.68	3.02	115.7	85.48	86.23	0.75	30.0	219
1380	8.94	3.07	115.9	85.95	86.70	0.75	29.7	227

TABLE 7 CONDENSER TESTS *

MADE ON A CYLINDRICAL SURFACE CONDENSER CONTAINING 300 SQ. FT. OF TUBE SURFACE

Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tubes, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Discharge Water, Deg. Fahr.	Temperature Rise, Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.	Ratio of Length in Ft. to Diameter in In.	B.t.u. Per Sq. Ft. Per Deg. Fahr. Difference Per Hour
No.	W	R	V_w	p	t_s	t_0	t_1	t_1-t_0	θ	$l \div d$	U
1	1504	122.0	0.952	2.15	106.7	85.0	93.0	8.0	17.4	15.657	281
2	1484	101.2	0.780	2.33	107.7	85.6	95.2	9.6	16.8	15.657	286
3	1495	80.3	0.620	2.5	110.5	85.5	98.0	12.5	18.05	15.657	275
4	1503	61.1	0.476	3.08	117.5	86.0	103.0	17.0	21.95	15.657	237
5	1469	51.5	0.393	3.42	121.0	85.0	107.0	22.0	23.32	15.657	237
6	1552	107.0	0.862	2.0	104.7	80.0	90.0	10.0	19.27	15.657	293
7	1487	95.7	0.738	2.11	104.3	79.2	91.8	12.6	18.05	15.657	332
8	1533	83.0	0.655	2.31	107.4	80.09	94.6	14.51	19.13	15.657	321
9	1497	61.4	0.478	2.73	112.8	81.6	98.1	16.5	21.95	15.657	224
10	1537	49.25	0.393	3.19	117.8	80.0	100.9	20.9	25.98	15.657	199
11	1590	114.0	0.942	1.82	100.0	74.5	83.5	9.0	20.7	15.657	263
12	1542	78.0	0.624	2.09	104.8	75.0	88.5	13.5	22.35	15.657	242
13	1595	60.2	0.498	2.45	109.2	75.1	93.9	18.8	23.42	15.657	245
14	1514	39.65	0.312	3.29	119.6	74.97	101.4	26.43	29.5	15.657	180
15	1600	103.5	0.861	1.58	94.2	70.0	80.0	10.0	18.73	15.657	293
16	1502	69.5	0.547	1.93	101.0	70.0	85.4	15.4	22.45	15.657	238
17	1529	49.5	0.393	2.55	113.3	70.0	92.7	22.7	30.6	15.657	187
18	1510	39.8	0.309	3.12	117.5	70.0	98.5	28.5	31.1	15.657	183
19	1560	106.0	0.860	1.23	88.7	65.0	74.5	9.5	18.5	15.657	283
20	1601	66.0	0.550	1.91	103.0	65.05	81.4	16.35	29.05	15.657	198
21	1520	49.7	0.393	2.32	111.9	64.2	86.7	22.5	35.35	15.657	161
22	1495	40.2	0.312	2.93	115.5	65.06	91.8	26.74	35.5	15.657	151
23	2050	96.8	1.030	2.48	108.6	85.0	96.4	11.4	17.28	15.657	436
24	1993	79.5	0.812	2.8	113.34	84.64	98.8	14.16	20.83	15.657	335
25	2054	59.2	0.631	3.36	118.9	85.04	103.96	18.92	23.15	15.657	327
26	1998	49.5	0.875	3.67	122.5	84.9	108.32	23.42	24.03	15.657	322
27	1964	101.0	1.030	2.28	106.6	81.1	92.9	11.8	19.0	15.657	412
28	1983	80.0	0.825	2.44	108.3	80.9	95.5	14.6	19.19	15.657	402
29	2038	58.93	0.622	2.97	114.3	80.1	99.0	18.9	23.5	15.657	322
30	2068	47.7	0.512	3.45	119.5	80.0	101.6	21.6	27.32	15.657	260
31	1908	95.0	0.940	2.14	103.3	75.0	87.2	12.2	21.65	15.657	341
32	1993	79.5	0.823	2.25	107.0	75.7	90.7	15.0	23.0	15.657	345
33	1986	49.75	0.510	2.82	114.5	75.0	98.0	23.0	26.35	15.657	288
34	2009	39.1	0.407	3.51	120.3	75.0	103.0	28.0	29.1	15.657	246
35	2016	111.5	1.170	1.64	95.0	70.2	78.8	8.6	20.2	15.657	320
36	2076	76.0	0.825	2.03	104.4	70.3	83.8	13.5	26.8	15.657	265
37	2017	66.8	0.700	2.1	105.5	70.3	87.3	17.0	25.8	15.657	297
38	1992	60.25	0.622	2.08	103.9	68.5	86.15	17.65	25.6	15.657	276
39	1963	50.25	0.512	2.53	110.0	70.0	91.4	21.4	27.95	15.657	252
40	2029	38.7	0.408	3.27	119.4	70.0	98.3	28.3	33.3	15.657	221
41	2106	94.2	1.030	1.52	92.2	65.0	76.0	11.0	21.2	15.657	343

* Tests made by R. W. Allen and published in Proceedings, Inst. of C. E., Feb. 28, 1905

TABLE 7 CONDENSER TEST—Con.

MADE ON A CYLINDRICAL SURFACE CONDENSER CONTAINING 300 SQ. FT. OF TUBE SURFACE

Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Discharge Water, Deg. Fahr.	Temperature Rise Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.	Ratio of Length in Ft. to Diameter in In.	B.t.u. Per Sq. Ft. Per Deg. Fahr. Difference Per Hr.
N.	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ	$l \div d$	U
42	2008	79.0	0.824	1.70	96.0	65.0	78.3	13.3	23.8	15.657	296
43	2154	55.73	0.623	2.10	103.5	65.0	82.7	17.7	28.78	15.657	246
44	1932	40.7	0.408	2.89	114.0	65.0	90.7	25.7	34.63	15.657	195
45	2440	121.0	1.535	2.48	107.7	85.0	92.7	7.7	18.6	15.657	407
46	2460	91.25	1.161	2.72	111.7	85.0	95.0	10.0	21.3	15.657	351
47	2520	78.8	1.032	2.98	113.5	84.75	96.8	12.05	22.2	15.657	360
48	2428	60.3	0.764	3.45	119.0	84.6	100.8	16.2	25.41	15.657	311
49	2520	117.3	1.532	2.15	103.2	80.1	88.6	8.5	18.55	15.657	453
50	2600	94.25	1.273	2.38	106.3	80.0	90.5	10.5	20.62	15.657	417
51	2580	77.0	1.044	2.71	110.8	80.5	94.1	13.6	22.85	15.657	394
52	2500	60.0	0.780	3.09	116.0	80.0	96.7	16.7	26.83	15.657	310
53	2580	118.5	1.589	1.84	99.7	75.0	83.0	8.0	20.4	15.657	400
54	2460	99.7	1.274	2.06	102.0	75.25	85.0	9.75	21.53	15.657	370
55	2484	80.0	1.032	2.33	106.4	74.9	87.4	12.5	24.75	15.657	339
56	2565	58.5	0.778	2.96	112.5	75.0	93.0	8.0	12.25	15.657	327
57	2520	39.1	0.512	3.88	123.6	75.0	100.3	25.3	34.42	15.657	241
58	2620	115.3	1.571	1.72	95.0	70.1	78.7	8.6	20.25	15.657	427
59	2424	101.0	1.272	1.81	98.2	69.7	79.0	9.3	23.6	15.657	322
60	2520	78.8	1.032	2.15	103.3	70.0	83.0	13.0	26.3	15.657	327
61	2468	40.0	0.512	3.54	120.2	70.0	95.7	25.7	35.8	15.657	236
62	2445	121.0	1.538	1.40	90.5	65.1	73.0	7.9	21.25	15.657	322
63	2400	93.5	1.165	1.65	94.2	64.7	74.7	10.0	24.2	15.657	309
64	2430	61.75	0.778	2.17	104.7	65.0	83.0	18.0	29.8	15.657	302
65	2515	39.3	0.512	3.22	117.2	65.0	91.0	26.0	37.75	15.657	228
66	2916	105.0	1.590	2.70	110.6	85.0	94.6	9.6	20.41	15.657	482
67	3041	80.5	1.270	2.97	113.6	85.0	97.0	12.0	22.08	15.657	438
68	2964	69.7	1.073	3.30	117.9	85.0	99.0	14.0	25.25	15.657	382
69	2968	58.5	0.901	3.68	121.8	84.9	102.2	17.3	27.39	15.657	366
70	3012	98.5	1.538	2.40	107.2	80.1	90.0	9.9	21.77	15.657	448
71	2960	84.75	1.303	2.60	109.0	80.0	91.6	11.6	22.75	15.657	427
72	2952	59.0	0.905	3.28	117.0	80.0	96.7	16.7	27.9	15.657	348
73	3048	106.5	1.689	1.94	101.0	75.0	83.0	8.0	21.8	15.657	397
74	3015	98.5	1.541	2.09	102.7	75.0	84.2	9.2	22.8	15.657	400
75	2970	81.7	1.260	2.28	106.2	75.0	87.0	12.0	24.4	15.657	398
76	2940	61.5	0.938	2.66	110.7	75.0	91.5	16.5	26.58	15.657	376
77	3015	49.75	0.778	3.34	118.75	75.0	96.0	21.0	32.1	15.657	326
78	3012	107.8	1.690	1.78	97.1	70.3	79.1	8.8	22.02	15.657	434
79	3000	99.0	1.538	1.83	99.1	70.25	80.25	10.0	23.5	15.657	421
80	2970	61.0	0.942	2.56	111.0	70.0	86.7	16.7	32.0	15.657	315
81	3171	37.9	0.624	3.82	122.5	69.7	96.2	26.5	38.1	15.657	277
82	2970	90.7	1.400	1.70	95.6	64.6	75.2	10.6	25.3	15.657	376
83	2965	69.5	1.070	2.03	101.3	65.0	79.5	14.5	28.35	15.657	351
84	3077	48.75	0.770	2.74	111.6	65.0	86.4	21.4	34.78	15.675	307

TABLE 8 HEATER TESTS *

Test Number	Circulating Water Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Total Tube Surface, Sq. Ft.	Ratio of Length in Ft. to Diameter in In.	Velocity of Water in Tubes, Ft. Per Sec.	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Discharge Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	$\text{Log}_e \frac{t_s - t_0}{t_s - t_1}$	Mean Temperature Difference, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Difference Per Hour	Remarks
No.	Q	R	S	$l \div d$	V_w	t_s	t_0	t_1	$t_1 - t_0$		θ	U	
1	176	20.0	0.1964	3.00	0.867	212	47.8	96.7	48.9	0.3528	138.5	314	Stanton. One copper tube, 0.5 in. outside diameter, 19 B.W.G., 18 in. long, tube in vertical position. Water circulated up in Tests 1-4, down in Tests 5-8
2	357	32.1	0.1964	3.00	1.76	212	47.8	78.0	30.2	0.2045	147.7	376	
3	464	36.5	0.1964	3.00	2.29	212	46.7	73.2	26.5	0.1747	151.8	411	
4	806	48.8	0.1964	3.00	3.97	212	54.3	74.1	19.8	0.1336	148.2	547	
5	176	15.5	0.1964	3.00	0.867	212	47.8	110.3	62.5	0.4811	130	430	
6	357	27.5	0.1964	3.00	1.76	212	47.8	83.0	35.2	0.2422	145.1	439	
7	464	31.4	0.1964	3.00	2.29	212	46.7	77.5	30.8	0.2070	148.7	489	
8	806	46.9	0.1964	3.00	3.97	212	54.3	74.9	20.6	0.1398	147.2	573	
9	702	11.22	1.065	7.23	1.33	255	58.0	140	82.0	0.5377	153.2	356	Nichols. One brass tube, 0.75 in. outside diameter, 18 B.W.G., 65 in. long. Tube vertical in Tests 9-11, horizontal in Tests 12-14. Water ran up in Tests 9-11
10	2421	26.4	1.065	7.23	4.60	255	58.0	93.5	35.5	0.1988	178.6	452	
11	3393	34.7	1.065	7.23	6.44	256	58.0	85.0	27.0	0.1467	184	467	
12	675	8.75	1.065	7.23	1.28	253	57.8	165	107.2	0.7975	134.5	505	
13	2670	21.8	1.065	7.23	5.06	253	58.0	101	43.0	0.2484	173	622	
14	3612	25.6	1.065	7.23	6.85	254	58.0	94.5	36.5	0.2058	177.4	698	

15	1216	8.12	13.09	16.0	0.373	212	74.0	193	119	1.9831	60	184	Hepburn Copper tubes, 1.25 in. outside diameter, 18 B.W.G., 20 in. long. Tubes horizontal. Corrugated tubes in Tests 24-27. Tests 20-23, 1 tube: Tests 15, 16, 26, 27, 2 tubes Tests 17-19, 24-25, 6 tubes
16	1342	9.11	13.09	16.0	0.412	212	74.0	180	106	1.4609	72.5	150	
17	2870	10.07	39.27	16.0	0.294	212	74.0	170	96.0	1.1894	80.7	86.9	
18	2292	7.87	39.27	16.0	0.222	212	72.0	195	123	2.1090	58.3	123	
19	1548	7.44	39.27	16.0	0.158	211	74.0	204	130	2.9745	43.7	117	
20	3082	9.73	6.045	16.0	1.89	217	71.0	170	99	1.1346	87.1	580	
21	2464	9.64	6.045	16.0	1.51	216	72.0	172	100	1.1860	84.3	484	
22	3708	10.60	6.045	16.0	2.275	216	71.0	162	91	0.9877	92.1	606	
23	1084	9.47	6.045	16.0	0.666	214	72.0	174	102	1.2669	80.6	227	
24	3930	5.93	45.2	16.0	0.402	211	41.0	204	163	3.1905	51.1	277	
25	4006	5.89	45.2	16.0	0.410	212	40.0	204	164	3.1294	52.4	277	
26	4440	7.53	15.07	16.0	1.361	215	67.0	195	128	2.0015	63.9	591	
27	3530	7.20	15.07	16.0	1.082	214	66.0	200	134	2.3582	56.9	542	
28	2799	6.65	54.2	3.333	0.048	215	62.0	207	145	2.9502	49.1	152	Hildreth Corrugated copper tubes, 1.5 in. outside diameter, 18 B.W.G. Vertical position, water circulated up. Tests 28-36, 24 tubes, 5 in. long. Tests 37-44, 36 tubes, 6 ft. 2 in. long.
29	3965	6.92	54.2	3.333	0.068	215	62.0	201.3	139.3	2.4132	57.8	176	
30	5223	7.36	54.2	3.333	0.090	215	62.0	193	131	1.9402	67.5	187	
31	5162	7.30	54.2	3.333	0.089	215	62.0	194.3	132.3	2.0001	66.6	189	
32	2558	6.58	54.2	3.333	0.044	215	62.0	208.5	146.5	3.1591	46 6	148	
33	3069	6.67	54.2	3.333	0.053	215	62.0	206.5	144.5	2.8903	50	164	
34	3993	6.92	54.2	3.333	0.069	215	62.0	201.3	139.3	2.4123	57.8	177	
35	4950	7.25	54.2	3.333	0.086	215	62.0	195.3	133.3	2.0503	65.1	187	
36	4805	7.15	54.2	3.333	0.083	215	62.0	197	135	2.1401	63.1	190	
37	1215	6.46	100.	4.10	0.014	215	62.0	211.3	149.3	3.7220	40.1	45.7	
38	3296	6.47	100.	4.10	0.038	215	62.0	211	149	3.6433	40.9	120	
39	3807	6.51	100.	4.10	0.044	215	62.0	210	148	3.4209	43.2	130	
40	4468	6.60	100.	4.10	0.0513	215	62.0	208	146	3.0842	47.3	138	
41	5879	6.75	100.	4.10	0.0675	215	62.0	205	143	2.7278	52.4	160	
42	6387	6.84	100	4.10	0.0735	215	62.0	203	141	2.5447	55.4	162	
43	7128	6.95	100.	4.10	0.082	215	62.0	200.8	138.8	2.3768	58.5	169	
44	7869	7.08	100.	4.10	0.031	215	62.0	198	136	2.1972	62.0	173	
45	4111	5.77	33.35	16.4	0.567	219	45.0	211.8	166.8	3.1201	53.4	385	Richter 3 corrugated copper tubes, 15 in. outside diameter, 18 B.W.G., 24 ft. 8 in. long. Horizontal.
46	5231	5.54	33 35	16.4	0.722	229	43.0	215.2	172.2	2.5810	66.7	406	
47	3936	5.22	33.35	16.4	0.543	233	45.0	227	182	3.4442	52.8	407	

* Tests made by H. L. Hepburn and published in *Power*. December 1901

TABLE 9 HEAT TRANSMISSION TESTS*

Table Number	Test Number	Circulating Water Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity, Ft. Per Sec.	Absolute Pressure, Lb. Per Sq. In.	Steam Temperature, Deg. Fahr.	Water Temperature, In, Deg. Fahr.	Water Temperature Out, Deg. Fahr.	Rise of Temperature, Deg. Fahr.	$\text{Log}_e \frac{t_s - t_0}{t_s - t_1}$	Mean Difference of Temperature, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Difference Per Hour.
No.	No.	Q	R	V_W	p	t_s	t_0	t_1	$t_1 - t_0$		θ	U
Brass Tube 37.0 In. Long, 1.93 In. Outside Diameter, 0.0788 In. Thick, Enclosing a Closed Tube 1.515 In. Outside Diameter. Outer Tube Water Area, 0.00467 Sq. Ft. Surface, 1.56 Sq. Ft. $\frac{l}{d} = 1.6$												
Table 2	4	305	12.1	0.29	14.7	212	79.0	159.0	80.0	0.9203	86.9	180
	5	305	11.96	0.29	14.7	212	78.5	159.3	80.8	0.9282	87.0	181
	6	468	17.0	0.446	14.7	212	90.0	146.7	56.7	0.6259	90.6	188
	7	463	17.3	0.44	14.7	212	90.0	146.0	56.0	0.6152	91.0	183
	8	832	24.6	0.793	14.7	212	98.6	137.9	39.3	0.4253	92.4	227
	9	868	24.5	0.826	14.7	212	98.3	137.7	33.4	0.4253	92.7	236
	10	2660	36.6	2.63	14.7	212	106.4	132.8	26.4	0.2867	92.1	488
	11	2605	36.3	2.49	14.7	212	106.2	132.8	26.6	0.2897	91.9	483
	11*a*	4060	46.2	3.87	14.7	212	106.4	127.3	20.9	0.2199	95.1	572
	11*b*	5740	62.0	5.47	14.7	212	109.0	124.6	15.6	0.1655	94.3	609
	11*c*	5840	57.5	5.56	14.7	212	106.2	123.0	16.8	0.1722	97.5	645
	11*d*	5975	74.4	5.69	14.7	212	123.4	136.4	13.0	0.1578	82.4	605
Table 3	12	1026	113.8	0.976	14.7	212	192.0	200.5	8.5	0.5539	15.3	368
	13	1026	94.8	0.976	14.7	212	187.5	197.7	10.2	0.5385	18.9	355
	14	1037	50.8	0.987	14.7	212	164.0	183.0	19.0	0.5032	37.8	334
	15	1022	33.6	0.974	14.7	212	134.3	163.0	28.7	0.4605	62.3	302
	16	1050	28.1	1.00	14.7	213	118.1	152.4	34.3	0.4479	76.6	302
	17	1049	25.0	1.00	14.7	213	104.0	142.5	38.5	0.4356	88.4	293
	18	1037	24.7	0.987	14.7	213	96.0	135.1	39.1	0.4055	96.5	269
	19	1022	23.5	0.974	14.7	213	84.0	125.1	41.1	0.3847	106.8	252
	20	1050	20.7	1.00	14.7	213	60.6	107.1	46.5	0.3646	127.4	246

Table 4	21	2250	144.3	2.14	14.7	212	191.2	197.9	6.7	0.3887	17.2	562
	22	2207	142.1	2.10	14.7	212	190.2	197.0	6.8	0.3730	18.2	529
	23	2107	122.3	2.01	14.7	212	186.9	194.8	7.9	0.3784	20.8	513
	24	2107	57.9	2.01	14.7	212	159.0	175.7	16.7	0.3784	44.0	513
	25	2098	59.3	2.00	14.7	212	158.5	174.8	16.3	0.3633	44.9	488
	26	2098	42.6	2.00	14.7	212	131.3	154.0	22.7	0.3300	68.8	444
	27	2110	34.8	2.10	14.7	212	105.0	132.8	27.8	0.3001	92.7	405
	28	2115	34.6	2.13	14.7	212	87.3	115.2	27.9	0.2531	110.2	343
	29	2098	28.5	2.00	14.7	212	49.6	83.5	33.9	0.2335	145.1	314
Table 5	30	3400	261.0	3.24	14.7	212	195.5	199.2	3.7	0.2546	14.51	555
	31	3370	276.0	3.21	14.7	212	195.5	199.0	3.5	0.2390	14.62	517
	32	3340	241.5	3.18	14.7	212	188.8	192.8	4.0	0.1894	21.1	406
	33	3450	56.8	3.28	14.7	212	141.0	158.0	17.0	0.2723	62.4	603
	34	3424	42.9	3.26	14.7	212	110.3	132.8	22.5	0.2484	90.5	547
	35	3395	34.0	3.23	14.7	212	49.1	77.5	28.4	0.1906	149.0	414
Table 6	36	5415	312.0	5.16	14.7	212	193.5	196.6	3.1	0.1823	17.0	633
	37	5480	84.8	5.22	14.7	212	161.5	172.9	11.4	0.2554	44.6	887
	38	5525	60.4	5.26	14.7	212	127.0	143.0	16.0	0.2078	77.0	737
	39	5415	42.6	5.16	14.7	212	49.3	72.0	22.7	0.1484	153.0	515
	40	5560	45.1	5.30	14.7	212	49.3	70.7	21.4	0.1398	153.0	498
Table 11	72–73	4710	37.3	4.48	14.7	212	43.5	69.4	25.9	0.1663	155.7	503
	74	4710	34.5	4.48	17.5	221	44.2	72.0	27.8	0.1697	164.0	512
	75	4710	31.3	4.48	23.0	236	44.2	74.5	30.3	0.1714	176.8	518
	76–77	4710	26.0	4.48	34.2	257.9	43.6	79.5	35.9	0.1831	196.0	554
	78–79	4630	25.3	4.41	39.3	266	43.3	79.9	36.6	0.1747	209.5	518
Table 12	81	2055	15.8	1.96	32.3	254.1	43.7	103.0	59.3	0.3300	179.6	435
	82	2055	16.8	1.96	28.8	248	43.7	99.5	55.8	0.3193	174.3	421
	83	2055	18.6	1.96	23.0	236	43.7	94.7	51.0	0.3075	166.0	404
	84	2055	21.6	1.96	17.5	221	43.3	87.8	44.5	0.2860	155.5	377
	85	2100	24.7	2.00	14.7	212	43.7	82.8	39.1	0.2639	148.1	355
	86	2067	26.6	1.97	13.2	206.6	43.7	80.2	36.5	0.2538	144.0	336
	87	2080	26.8	1.98	12.5	203.9	43.7	79.9	36.2	0.2561	141.1	342
	88	2055	31.5	1.96	9.4	190.4	43.7	74.9	31.2	0.2390	130.8	314

* Tests made by Gustav Hagemann and published in the Proceedings, Inst.C.E., vol. 22, 1883

TABLE 10 CONDENSER TUBE

Test Number	Steam Condensed Per Hour	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per. Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Hot Well Temperature, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg Fahr.
No.	W	R	V_w	p	t_s	t_p	t_0	t_p
1	2.374	41.1	0.057	1.56	93.3	91.55	41.33	68.40
2	5.818	17.0	0.58	5.00	134.	131.5	41.33	104.7
3	18.93	40.0	0.443	17.99	187.3	174.0	41.28	66.60
4	17.83	44.7	0.465	15.32	180.0	167.5	40.93	63.78
5	11.21	52.7	0.346	9.09	157.7	142.9	40.62	61.05
6	15.50	40.8	0.369	13.33	174.0	157.9	40.66	66.55
14	4.36	15.6	0.040	29.90	212.	75.03	41.68	119.1
17	2.985	63.5	0.798	0.96	78.0	73.0	43.83	61.7
18	2.983	6.85	0.086	18.33	188.2	183.8	43.20	178.0
19	3.27	13.3	0.184	4.97	133.7	129.9	43.91	123.1
20	1.83	33.4	0.258	1.19	84.5	78.3	44.35	78.15
21	11.46	6.67	0.322	25.13	203.3	189.0	43.45	190.6
34	14.81	44.3	2.67	2.16	104	103.5	47.59	72.6
35	30.84	40.3	5.24	7.88	151.7	140.8	47.51	73.33
62	7.40	64.0	5.00	1.115	82.6	78.65	42.93	61.80
63	23.79	20.7	5.20	7.29	148.7	138.0	42.93	94.70
64	44.75	12.1	5.72	27.27	207.2	190.1	42.93	124.6
39	3.023	19.0	0.670	2.19	104.4	103.2	44.11	101.7
40	3.629	5.90	0.226	24.49	202	193.0	45.09	192.5
41	3.390	39.3	1.41	1.04	80.5	77.15	44.82	73.15
42	10.52	14.7	1.63	6.06	141.3	121.2	44.38	117.8
43	8.737	11.4	1.05	6.93	146.7	143.4	44.51	134.2
47	5.550	81.9	4.80	1.59	93.85	60.18	43.71	57.80
65	5.01	30.1	1.59	1.82	98.2	82.95	44.55	80.30
66	13.05	14.2	1.95	5.45	137.1	133.	44.55	118.0
67	25.81	8.25	2.24	22.77	198.7	186.5	44.55	160.2
68	3.22	9.18	0.146	10.06	161.9	149.2	48.91	153.2
70	22.18	18.1	2.07	21.53	196.0	178.0	48.44	107.1
73	27.75	23.6	3.25	21.07	194.9	179.3	45.13	87.4
75	2.65	235.	3.09	1.18	84.45	65.4	45.02	50.56
83	3.284	6.99	0.114	30.02	212.3	96.0	41.00	195.2
84	26.43	21.0	2.17	28.52	209.7	201.2	56.40	102.0
85	23.75	19.2	1.78	29.54	211.5	192.3	56.40	108.15
97	11.81	47.7	0.842	4.04	126.1	120.9	62.40	85.15
98	27.31	24.2	0.990	14.45	177.4	168.7	62.00	105.25
99	38.01	20.6	1.17	24.49	202.0	190.6	61.60	111.2
148	5.14	23.2	1.44	1.601	94.1	91.1	40.50	88.00
149	13.63	10.1	1.66	8.39	154.2	150.	40.50	142.2
150	9.71	35.0	4.10	1.412	90.1	82.5	39.56	70.4
151	23.36	14.9	4.22	7.192	148.0	144.3	39.56	109.0

* Tests made by J. P. Joule and published in Phil. Trans. Royal Soc., 1861, p. 133.

HEAT TRANSFER TESTS*

Temperature Rise Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.	Ratio of Length in Ft. to Diameter in In.	B.t.u. Per Sq. Ft. Per Deg. Fahr. Per Hour	
$t_1 - t_0$	θ	$l \div d$	U	
27.07	36.85	6.35	108.7	Copper steam tube, 4 in. long, 0.75 in. outside diameter, 0.63 in. inside diameter. Total inside surface, 0.66 sq. ft. Water area, 1.0976 sq. in. Outer tube 1.4 in. inside diameter. Flow counter-current.
63.37	55.0	6.35	172	
25.32	133	6.36	219	
22.85	128.2	6.35	216	
20.43	107.1	6.35	171	
25.89	120.2	6.35	206	
77.42	127.2	6.35	62.5	
17.87	24.2	6.35	212	Same steam tube. Outer tube 0.87 in. inside diameter. Water area 0.1523 sq. in. Flow counter-current except Tests 34 and 35, in which steam and water flow in the same direction.
134.8	50.8	6.35	82	
79.19	37.1	6.35	141	
33.80	18.3	6.35	171	
147.15	58.1	6.35	293.5	
25.01	42.8	6.35	349	
25.82	90.6	6.35	538	
18.87	29.4	6.35	460	Same steam tube. Outer tube 0.8 in. inside diameter. Inner tube rubbed with oil. Water area 0.0609 sq. in. Flow counter-current.
51.77	77.0	6.35	503	
81.67	118.6	6.35	566	
57.59	18.5	6.35	271	Same steam tube. Outer tube 0.8 in. inside diameter. Water area 0.0609 sq. in. Counter-current.
147.41	52.5	6.35	91	
28.33	17.9	6.35	320	
73.42	51.9	6.35	332	
89.69	42.6	6.35	317	
14.09	42.9	6.35	226	
35.75	32.6	6.35	250	Same tubes. Oil cleaned off after Tests 62–64. Water and steam in same direction.
73.45	46.5	6.35	442	
115.65	81.8	6.35	456	
104.29	40.7	7.69	139	Lead tube 4 ft. long, 0.77 in. outside diameter, 0.52 in. inside diameter. Outer tube 0.87 in. inside diameter. Inside surface 0.545 sq. ft. Water area 0.1288 sq. in. Counter-current flow.
58.66	115.7	7.69	389	
42.27	127.8	7.69	398	
5.54	36.7	7.69	173	
154.2	67.0	7.69	97	
45.6	128.7	6.65	313	Iron tube 4 ft. long, 0.74 in. outside diameter, 0.602 in. inside diameter. Outer tube 0.87 in. inside diameter. Surface 0.63 sq. ft. Water area 0.164 sq. in. Counter current.
51.75	127.5	6.65	294	
22.75	51.5	6.35	377	Copper tube again. Outer tube 1.4 in. inside diameter. Spiral 0.1 in. diameter copper wire 30 turns around inner tube—half l.h. Water area 0.429 sq. in. Counter-current.
43.25	92.1	6.35	470	
49.6	113.5	6.35	518	
47.5	20.8	6.65	431	Iron tube as above. Outer tube 0.87 in. inside diameter. Spiral of 55 turns 0.055 in. copper wire wound on inner tube. Water area 0.053 sq. in. Tests 148, 149 steam and water in same direction. Tests 150, 151 counter-current.
101.7	45.2	6.65	492	
30.84	32.8	6.65	507	
69.44	67.9	6.65	566	

TABLE 11 CONDENSER TESTS*

SURFACE = 25000 SQ. FT. TWO PASS. WATER AREA. 13.22 SQ. FT. 5960 TUBES, 16 FT. LONG, 1 IN. OUTSIDE DIAMETER, 18 B.W.G.

Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Absolute Pressure of Steam, In. of Mercury	Velocity of Water, Ft. Per Sec.	Temperature of Steam, Deg. Fahr.	Hot Well Temperature, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature of Rise Water, Deg. Fahr.	$\text{Log}_e \frac{t_s - t_o}{t_s - t_1}$	Mean Temperature Difference, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Fahr., Difference Per Hour
No.	W	R	p	V_w	t_s	t_p	t_o	t_1	$t_1 - t_o$	log	θ	U
38	237480	53.5	1.51	42.7	92	71.2	37.7	57.3	19.6	0.445	43.8	227
39	187193	48.2	1.59	3.04	94	76.2	39.9	62.5	22.6	0.542	41.7	195
40	170661	52.9	1.22	3.04	85	71.0	32.0	51.8	19.8	0.470	42.1	168
41	160229	46.4	1.30	2.50	87	73.4	34.0	56.8	22.8	0.565	40.3	168
42	147142	42.7	1.32	2.11	88	75.2	31.8	56.7	24.9	0.588	42.4	147
43	138766	44.2	1.47	2.06	91	80.2	32.8	57.1	24.3	0.542	44.8	132
44	122689	107.7	0.94	4.44	77	59.4	31.6	42.0	10.4	0.262	39.6	139
48	114372	118	1.20	4.54	85	60.6	32.9	42.1	9.2	0.1906	48.3	103
51	133462	150	1.18	6.72	84	65.2	37.5	43.1	5.6	0.1310	42.7	104
54	176565	77.1	0.94	4.57	77	57.3	33.5	47.8	14.3	0.3988	35.6	218
55	99210	112	1.16	3.73	84	58.6	33.1	41.3	8.2	0.1740	47.1	77
56	158112	63.4	1.02	3.37	80	60.7	33.4	50.1	16.7	0.4447	37.5	178
57	182508	77.5	0.86	4.75	74	53.2	33.3	47.6	14.3	0.432	33.1	244
58	81533	153	0.98	4.20	78	53.9	33.2	39.5	6.3	0.151	41.7	75
59	120863	108	0.94	4.67	77	59.1	33.4	43.7	10.3	0.270	38.2	141
60	141930	82.9	0.88	3.94	75	59.6	33.3	46.0	12.7	0.365	34.8	172
61	143958	108	1.00	5.22	79	61.7	33.1	47.2	14.1	0.365	38.6	227
62	206603	49.0	1.18	3.41	84	62.8	33.6	56.0	22.4	0.588	38.1	239
5	150170	89.0	1.89	4.50	100	88.1	72.1	84.0	11.9	0.554	21.5	296
6	167190	8.05	1.58	4.52	94	87.6	74.7	87.7	13.1	1.135	11.7	605
7	164945	78.3	1.37	4.35	89	85.5	72.5	85.0	13.5	1.703	7.91	889
8	161612	86.5	1.48	4.70	92	86.9	74.4	86.6	12.3	1.182	10.3	659
9	164458	79.0	1.74	4.36	97	87.8	72.8	86.3	13.5	0.815	16.6	426
10	185100	93.5	2.01	5.82	102	89.5	72.0	83.3	11.3	0.470	24.0	325
11	136850	94.5	2.00	4.35	102	87.3	72.4	83.5	11.1	0.470	23.6	243
12	192290	76.5	1.93	4.94	100	90.7	75.4	89.2	13.8	0.820	16.8	484
13	156470	96.0	1.94	5.06	100	88.2	72.8	83.8	11.0	0.519	21.2	311
14	176210	78.6	1.63	4.65	94	86.4	73.0	86.6	13.6	1.044	13.1	576
15	167103	69.0	2.41	3.88	107	91.8	78.2	93.5	15.3	0.751	20.4	347
16	167088	82.0	2.50	4.61	109	92.9	78.6	91.5	12.9	0.554	23.2	303
17	179170	81.0	2.30	4.86	106	86.4	73.6	86.7	13.1	0.519	25.3	300
18	149148	98.0.	2.27	4.92	106	89.7	72.8	83.6	10.8	0.382	27.5	229
19	201351	66.0	2.14	4.46	104	90.9	72.2	88.2	16.0	0.698	22.9	371
20	196680	51.0	2.17	3.37	104	90.3	72.6	93.7	21.1	1.105	19.1	444
21	144399	85.0	1.89	4.13	99	87.8	72.5	84.4	11.9	0.593	20.1	291
23	195514	75.5	2.20	4.95	105	91.1	73.0	87.0	14.0	0.571	24.5	337
24	173150	78.5	2.13	4.56	103	89.8	73.3	86.8	13.5	0.599	22.5	326
25	134635	101	2.14	4.56	104	88.8	72.3	82.8	10.5	0.399	26.3	207
26	161983	91.0	2.44	4.93	108	88.2	73.1	84.9	11.8	0.412	28.6	246

* Tests run on 59th Street Exhaust Turbine Base Condenser by H. G. Stott and R. J. S. Pigott and published in The Journal of the Society, March 1910.

TABLE 12 HEAT TRANSMISSION*

Series Number	Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Water Velocity, Ft. Per Sec.	Absolute Pressure, In. of Mercury	Steam Temperature, Deg. Fahr.	Hot Well Temperature, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	$\text{Log}_e \frac{t_s - t_0}{t_s - t_1}$	Mean Temperature Difference, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Difference Per Hour.
No.	No.	W	R	V_w	p	t_s	t_p	t_0	t_1	$t_1 - t_0$		θ	U
Series† A	987	1739	31.8	4.45	1.36	88.9	90.0	45.3	75.3	30.0	1.1663	25.7	646
	988	1992	28.2	4.52	1.63	94.7	92.4	45.2	79.0	33.8	1.1474	29.5	645
	989	1844	24.6	3.66	2.03	101.9	97.1	45.3	85.0	39.7	1.2090	32.8	549
	990	1986	17.7	2.85	2.46	108.4	112.0	45.5	101.0	55.5	2.1401	25.9	753
	991	1899	13.3	2.06	3.97	125.4	128.9	45.7	118.7	73.0	2.4759	29.5	623
	992	1781	8.5	1.24	11.94	169.2	171.6	46.0	161.7	115.7	2.7972	41.4	422
Series B	998	1121	49.2	6.38	0.80	72.6	72.2	46.0	66.7	20.7	1.504	13.15	829
	999	1101	41.1	5.20	0.80	72.6	75.1	46.0	70.5	24.5	2.53	9.68	1145
	1000	1073	34.5	4.23	0.90	76.2	79.5	46.2	75.8	29.6	4.32	6.86	1600
	1005	1517	24.2	4.21	1.41	90.1	95.4	46.5	89.8	43.3	4.98	8.69	1830
	1007	1400	11.6	1.82	5.36	136.6	138.6	47.5	135.6	88.5	4.48	19.6	729
	1008	1781	30.9	6.37	1.16	83.9	88.2	46.5	81.3	34.8	2.667	13.0	1465
	1009	1716	26.7	5.28	1.21	85.2	90.09	46.8	84.6	37.8	4.15	9.11	1905
	1010	1987	18.4	4.21	2.13	103.3	106.1	46.2	101.3	55.1	3.51	15.7	1283
	1011	1840	14.3	3.00	3.33	119.0	121.9	46.4	118.2	71.3	4.50	15.8	1184
Series C	1014	1265	45.9	4.56	1.03	80.2	76.3	46.0	68.0	22.0	1.0367	21.2	602
	1015	1302	35.9	3.66	1.03	80.2	79.9	46.0	72.5	26.5	1.4907	17.7	695
	1016	1194	30.7	2.85	1.18	84.4	86.2	46.1	78.7	32.6	1.9051	17.1	698
	1017	1191	22.3	2.04	1.55	93.1	95.3	46.3	88.3	42.0	2.2762	18.5	603
	1018	1170	13.8	1.22	3.93	125.0	123.5	46.9	119.7	72.8	2.686	27.1	433
	1031	1180	22.4	2.03	1.47	91.4	90.2	42.6	84.5	41.9	1.943	21.5	512
	1032	1148	51.5	4.65	0.95	77.8	76.5	42.0	60.8	18.8	0.7324	25.8	433
	1033	1681	35.3	4.66	0.98	78.7	77.5	42.0	68.5	26.5	1.2809	20.7	759
	1034	1570	16.8	2.04	2.56	110.0	109.7	42.5	102.0	59.5	2.1318	27.9	561
	1035	1848	14.2	2.03	3.48	120.5	121.9	42.5	114.0	71.5	2.4849	28.8	653
Series D	1055	2208	26.0	4.63	1.95	100.4	101.3	41.3	77.2	35.9	0.9322	38.5	865
	1056	2214	20.5	3.67	2.70	111.6	114.0	41.4	88.3	46.9	1.1019	42.7	806
	1057	2288	15.3	2.83	4.43	129.4	132.0	41.5	104.3	62.8	1.2528	50.1	705
	1058	1788	31.3	4.51	1.68	95.7	104.0	41.2	72.0	30.8	0.8329	37.1	753
	1059	1753	25.7	3.53	1.92	100.0	106.0	41.4	79.3	37.9	1.0403	36.4	757
	1060	1776	19.9	2.85	2.65	111.1	115.3	41.5	89.7	48.2	1.1787	40.9	672
	1061	1722	14.4	2.01	4.40	129.0	132.0	41.7	108.0	66.3	1.4255	46.6	570
Series E	1092	1157	47.6	6.48	0.98	76.8	75.0	43.5	61.8	18.3	0.7975	23.0	708
	1093	1105	32.1	4.17	1.13	83.1	81.7	44.1	72.5	28.4	1.3029	21.8	745
	1100	1649	33.6	6.47	0.90	76.1	78.7	40.0	62.6	22.6	0.9821	24.1	876
	1099	1646	22.1	4.17	1.40	90.0	94.0	40.0	82.0	42.0	2.1199	19.8	1242
	1098	1559	13.9	2.40	2.90	114.0	120.0	40.0	107.6	67.6	2.459	27.5	859
	1095	2191	25.7	6.52	1.43	90.5	88.0	40.0	76.2	36.2	1.2613	28.7	1145
	1096	2099	17.2	4.17	2.30	106.0	107.7	40.0	95.3	55.3	1.8197	30.4	1060
	1097	2010	10.4	2.39	5.70	139.0	142.0	40.3	129.7	85.4	2.3656	36.1	797

* Test made by R. L. Weighton and published in the Proceedings of the I. N. A., April 5, 1906.

† Series *A*—100 Sq. ft. surface—Ordinary air pump. Tubes [illegible] in. outside diameter, 16 ft. total length
Series *B*—100 sq. ft. surface—Dry air pump-cores.
Series *C*—100 sq. ft. surface—Dry air pump.
Series *E*— 62 sq. ft. surface—Ordinary air pump. Tubes [illegible] in. outside diameter, 10 ft. total length.
Series *F*— 62 sq. ft. surface—Dry air pump-cores.

TABLE 13 CONDENSER TESTS*

Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Average Velocity of Water, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Hot Well Temperature, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature End First Pass, Deg. Fahr.	Temperature End Second Pass, Deg. Fahr.	Temperature End Third Pass, Deg. Fahr.
No.	W	R	V_w	p	t_s	t_p	t_0	t_a	t_b	t_c
1	4000	51.4	See Table 13a	1.15	82.25	58.45	50.39	51.7	61.6	65.9
2	3985	34.6		1.39	90.0	68.9	50.42	52.6	69.9	75.35
3	4023	24.0		2.05	102.0	79.5	50.37	61.1	80.7	87.8
4	4050	18.73		2.79	113.0	89.6	50.4	65.4	90.5	99.0
5	2453	86.7		0.98	79.9	52.7	50.4	50.62	54.7	57.5
6	2427	49.8		1.06	81 9	54.0	50.4	50.93	60.4	65.8
7	2421	37.8		1.16	84.6	56.65	50.42	53.05	67.55	72.85
8	2421	30.15		1.42	90.0	65.65	50.42	56.57	73.9	79.35
9	2417	22.87		1.95	101.0	75.55	50.43	60.9	83.8	90.15
10	2457	16.7		3.05	115.5	93.0	50.45	67.6	99.15	106.5
101	12800	98		1.10	80.6	68.9	49.1			
102	7740	169		0.90	75.2	58.1	49.1			
103	1876	596		0.70	68.0	47.3	45.5			
111	154,400	21.1	7.52	5.27	133		59.2	73.4		
6-1	7665	32.6		1.55	93.2	65.85	50.76			
6-2	4837	43.1		0.93	80.6	57.2	50.76			
6-3	6250	38.4		1.11	84.25	62.42	50.76			
6-5	7685	32.1		1.98	102.05	79.17	50.76			
6-6	5890	40.4		1.49	93.55	71.08	50.76			
6-7	4750	44.1		1.30	90.95	68.6	50.76			
6-8	6070	41.9		1.40	92.15	70.0	50.76			
4-1	6870	39.2	1.275	1.15	82.3	64.4	50.55	61.1		
4-2	7018	28.5	0.945	1.52	92.3	69.1	50.55	68.6		
4-3	6890	22.1	0.719	2.04	102.3	77.7	50.71	79.5		
4-4	7133	17.4	0.588	2.87	114.1	87.5	50.55	93.8		
411	7133	36.9	1.246	2.16	104.2	87.3	71.9	88.3		
410	5760	46.0	1.256	1.67	95.6	80.8	70.2	82.5		
412	3898	67.3	1.241	1.32	88.9	77.7	71.6	79.0		
4-8	6865	24.9	0.810	1.79	97.9	71.4	50.55	75.6		
4-9	4542	38.0	0.816	1.12	81.9	62.8	50.55	63.35		
413	3221	54.5	0.829	0.80	72.7	58.1	50.36	55.5		
414	3182	82.3	1.239	0.65	66.6	54.5	50.36	51.1		
4-5	7200	19.6	0.668	2.48	108	82.7	50.55	85.15		
4-6	7050	19.9	0.663	2.93	114.1	69.7	50.55	62.41		
4-7	6975	20.2	0.668	3.40	119.8	61.2	50.55	54.05		

* Tests made by E. Josse and published in Zeitschrift des Vereines deutscher Ingenieure, February–March 1909.

† $\frac{l}{d}$ and U figured on inside diameter of tubes in all tests

‡ Test 111 was on a turbine condenser with 6085 sq. ft. of surface, Number and size of tubes not given

TABLE 13 CONDENSER TESTS—Con.

Temperature of Discharge Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.	Ratio Length in Ft. to Diameter in In.	B.t.u. Per Sq. Ft. Per Deg., Difference Per Hour	$\log_e \frac{t_s - t_0}{t_s - t_1}$	
t_1	$t_1 - t_0$	θ	$l \div d$	U		
71.23	20.84	19.60	23.6†	710	1.0613	Double condenser of 307 sq. ft. surface. Tubes 0.59 in. inside diameter in upper and 0.51 in. inside diameter in lower shell. 620 tubes. Length of water passage 13.93 ft.
81.15	30.73	20.50	23.6	673	1.4974	
94.1	43.73	23.3	23.6	590	1.8779	
105.7	55.3	25.7	23.6	531	2.1494	
62.37	11.97	23.1	23.6	359	0.5188	
71.2	20.8	19.3	23.6	425	1.0791	
77.9	27.48	16.9	23.6	485	1.6292	
84.4	33.98	17.38	23.6	464	1.9559	
95.8	45.37	19.95	23.6	408	2.2742	
111.7	61.25	15.95	23.6	512	3.8396	
59.9	10.8	25.8		280	0.4187	Surface 1883 sq. ft., size of tubes not reported.
55.4	6.3	22.75		194	0.277	
47.3	1.8	21.5		492	0.0839	
‡103.5	44.3	48.3		490	0.9163	
83.70	32.94	22.0		388	1.497	Condenser of 959 sq. ft. surface. In Tests 1-3 the tube contained spirals. Tests 5-8 had plain tubes.
75.4	24.66	14.1		378	1.748	
78.4	27.66	15.85		435	1.746	
82.6	31.86	32.8		250	0.9708	
76.85	25.90	27.65		234	0.940	
75.15	24.39	26.15		203	0.9322	
75.7	24.94	27.0		243	0.9243	
77.8	27.25	13.95	21.3	553	1.953	Double condenser. Total surface 962 sq. ft. 688 tubes 708 in. inside diameter, 787 in. outside diameter, half in. in each section. Area water pass 0.94 sq. ft. Total length water pass 15.08 ft.
88.3	37.75	16.1	21.3	488	2.344	
98.8	48.09	17.89	21.3	431	2.689	
110.1	59.55	21.5	21.3	395	2.766	
100.9	29.0	12.7	21.3	630	2.281	
93.1	22.2	9.59	21.3	640	2.318	
87.4	15.8	6.46	21.3	668	2.444	
93.9	43.35	17.53	21.3	443	2.470	
79.15	28.6	11.75	21.3	441	2.434	
69.95	19.59	9.36	21.3	379	2.094	
63.35	12.99	8.07	21.3	441	1.609	
104.6	54.05	19.11	21.3	418	2.827	
104.9	54.35	28.1	21.3	283	1.933	
104.9	54.35	35.4	21.3	227	1.535	

TABLE 13a TESTS 1 TO 10

WATER VELOCITIES, FT. PER SEC.

Test No.		1	2	3	4	5	6	7	8	9	10
Upper Condenser	Upper Tubes..........	5.52	3.705	2.60	2.035	5.72	3.25	2.46	1.96	1.484	1.10
	Center (Cross) Tubes.	2.54	1.71	1.194	0.94	2.63	1.50	1.135	0.907	0.684	0.51
	Lower Tubes.........	3.61	2.424	1.70	1.33	3.74	2.13	1.61	1.29	0.973	0.723
Lower Condenser		3.03	2.04	1.43	1.12	3.15	1.79	1.35	1.08	0.815	0.605

TABLE 14 HEAT TRANSMISSION TESTS*

MADE ON TUBE OF SHELBY COLD DRAWN STEEL, 1.253 IN. OUTSIDE DIAMETER, 0.985 IN. INSIDE DIAMETER, 6 FT. 7¼ IN. LONG INSIDE CONDENSER†, $\frac{l}{d} = 5.27$, $S = 2.14$ SQ. FT.

Series Number	Test Number	Circulating Water Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, Lb. Per Sq. In.	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Discharge Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	$\text{Log}_e \frac{t_s - t_0}{t_s - t_1}$	Mean Temperature Difference, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Fahr., Per Difference Per Hour
	No.	Q	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$		θ	U
Series *A*	1	19100	98.4	16.07	14.38	210.9	56.92	66.75	9.83	0.0658	149.0	587
	2	15800	80.2	13.29	14.38	210.9	58.20	70.25	12.05	0.0824	146.3	608
	3	14150	72.4	11.93	14.38	210.9	58.55	71.90	13.35	0.0915	146.0	605
	4	12250	66.4	10.33	14.38	210.9	58.63	73.20	14.57	0.1027	141.9	588
	5	10560	58.1	8.90	14.38	210.9	58.20	74.82	16.62	0.1142	145.0	565
	6	8820	55.6	7.43	14.38	210.9	57.89	75.28	17.39	0.1221	142.5	503
	7	7200	47.6	6.07	14.38	210.9	58.20	78.52	20.32	0.1424	142.6	480
	8	4860	36.9	4.11	14.38	210.9	58.29	84.49	26.20	0.1890	138.6	430
	9	3310	28.7	2.80	14.38	210.9	58.37	92.00	33.63	0.2493	135.0	385
	10	1740	19.5	1.48	14.38	210.9	58.91	108.4	49.50	0.3934	126.0	319
	11	427	8.38	0.37	14.38	210.9	60.10	175.5	115.4	1.4481	79.8	289
Series *B*	1	19900	62.3	16.78	44.49	273.6	58.55	73.35	14.80	0.0724	204.5	673
	2	14680	46.5	12.37	45.08	274.4	58.32	78.12	19.80	0.0962	206.0	658
	3	17670	53.3	14.89	44.56	273.7	58.15	75.45	17.30	0.0816	212.0	673
	4	12030	40.0	10.15	44.71	273.9	57.90	80.94	23.04	0.1133	203.0	638
	5	9350	33.2	7.89	44.85	274.1	58.05	85.83	27.80	0.1354	205.0	591
	6	6970	25.5	5.88	44.85	274.1	58.10	92.88	34.78	0.1757	198.0	572
	7	3458	16.0	2.94	44.85	274.1	62.87	120.46	57.59	0.3185	181.0	514
	8	4580	20.4	3.89	45.15	274.5	63.28	108.5	45.22	0.2398	188.5	514
	9	2141	11.2	1.84	45.15	274.5	63.73	145.9	82.17	0.4947	166.0	494
	10	1680	9.74	1.45	45.08	274.4	67.55	162.2	94.65	0.6114	155.0	480
Series *C*	1	20870	51.5	17.64	74.15	306.6	67.54	85.00	17.46	0.0770	227.0	750
	2	18400	45.7	15.50	74.15	306.6	67.54	87.19	19.65	0.0862	228.0	741
	3	13570	34.9	11.43	74.05	306.5	67.54	93.30	25.76	0.1142	225.0	725
	4	6280	18.3	5.33	74.37	306.8	58.73	107.7	48.96	0.2199	223.0	645
	5	4910	15.2	4.17	74.59	307.0	58.89	118.05	59.16	0.2715	218.0	622
	6	3720	12.7	3.17	74.59	307.0	59.27	129.7	70.43	0.3345	210.0	582
	7	2550	9.47	2.19	75.03	307.4	59.52	154.35	94.83	0.4806	197.0	574
Series *D*	1	20320	38.6	17.13	103.7	330.2	57.67	80.50	22.83	0.0872	262.0	830
	2	16630	33.7	14.05	103.4	330.0	57.67	83.88	26.21	0.1018	258.0	790
	3	12300	27.0	10.39	103.4	330.0	58.28	90.92	32.64	0.1284	254.0	740
	4	9530	22.2	8.06	103.7	330.2	58.17	97.90	39.73	0.1579	252.0	702
	5	5000	14.2	4.25	103.7	330.2	58.50	120.6	62.10	0.2586	240.0	604
	6	2680	8.60	2.31	103.7	330.2	58.89	161.5	102.61	0.4762	215.0	597

* Tests made by J. K. Clement and C. M. Garland and published in Bulletin 40 of the University of Illinois, September 27, 1909.

†The condenser was a specially designed apparatus for experimental work at the Engineering Experiment Station of the University of Illinois.

APPENDIX NO. 2

REVIEW OF RESULTS OBTAINED BY DIFFERENT EXPERIMENTERS

CONDENSER TUBE EXPERIMENTS BY J. P. JOULE

Philosophical Transactions, Royal Society, 1861

43 The apparatus used in these tests consisted of a steam boiler, with a 1-in. pipe leading to a vertical condenser tube enclosed by a water pipe of slightly greater diameter. The steam was condensed in passing downward through the condenser tube, and the water of condensation ran out the bottom, where it was collected and weighed in a suitable tank. The cooling water was brought into the water jacket at either top or bottom and taken from the other end to another tank to be weighed. Thus, either counter-flow or parallel-flow was obtained, the cooling water passing through the annular space around the condenser tube while the steam passed on the inside of the tube. Suitable thermometers and mercury columns were provided to determine the temperature and pressure of the steam, the head on the circulating water, temperature rise of the water and the mean temperature difference.

44 The tubes used were of various sizes, thicknesses and material and the water pipe also varied in size. For some tests helical channels were provided for the water by winding wire on the inner tube, giving the circulating water a whirling motion. The length of the tests varied from twenty minutes to an hour.

CONCLUSIONS

45 The following is a summary of his principal conclusions:

a The pressure in the vacuous space is sensibly equal in all parts.

b In the arrangement in which the steam is introduced into a tube whilst the refrigerating water is transmitted along a concentric space between the steam tube and a larger tube in which it is placed, it is a matter of indifference in which direction the water is transmitted, hence,

c The temperature of the vacuous space is sensibly equal in all parts.

d The resistance to conduction is to be attributed almost entirely to the film of water in immediate contact with the outside and inside surfaces of the tube and is little influenced by the kind of metal of which the tube is composed, or by its thickness in the limits of ordinary tubes, or even by the state of its surface as to greasiness or oxidation.

e The narrowing of the steam space by placing a rod in the axis of the steam tube does not produce any sensible effect.

f The conductivity increases as the rapidity of the stream of water is augmented. In the circumstances of my experiments, the conduction was nearly proportional to the cube root of the velocity of the water; but at very low velocities it evidently increases more rapidly than according to this law, whilst at very high velocities it increases less and less rapidly as it gradually approaches a limit determined by the resistance of the metal and of the film of water adhering to the inside surface of the tube.

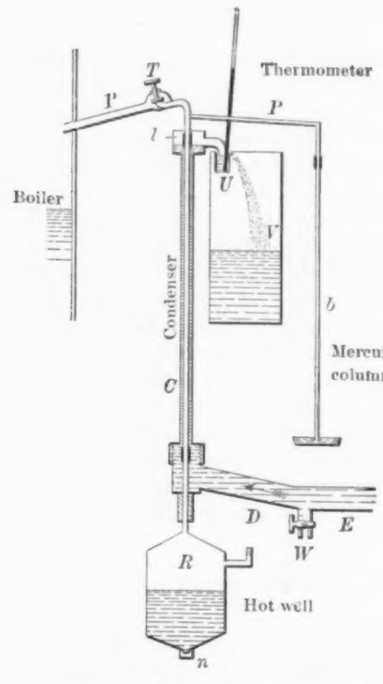


FIG. 12 JOULE'S APPARATUS

g The conductivity increases so slowly in relation to the height of the head of water, that the limit to the economical increase of the latter is soon attained.

h By means of a contrivance for the automatical agitation of the particles of the refrigerating stream, such as the spirals I have employed, an improvement in the conductivity for a given head of water is obtained.

i The total heat of steam above 0 deg. cent. determined by the average of 151 experiments, is 644.28 heat units for a pressure of 47.042 in.

EXPERIMENTS ON SURFACE CONDENSATION

ABSTRACT OF A PAPER BY JAMES ALEXANDER SMITH, READ BEFORE THE VICTORIAN INSTITUTE OF ENGINEERS, DECEMBER 6, 1905

Engineering, March 23, 1906

46 This paper is a sequel to a former paper on Air in Relation to Boiler Feed, Engineering, October 7, 1904.

47 The preliminary experiments were made with closed glass tubes containing bromine both with and without air in the vapor space. The low boiling point,

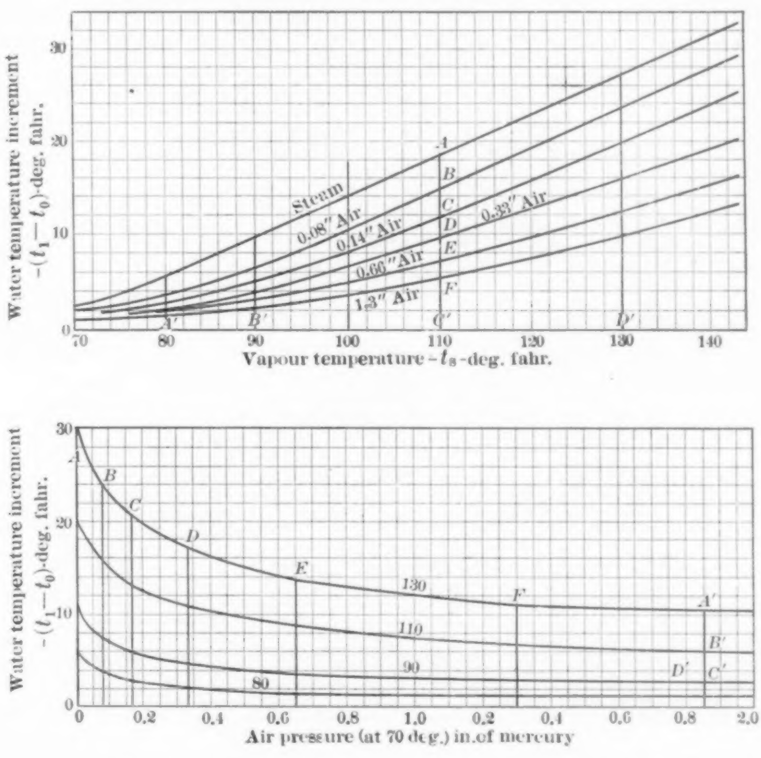


FIG. 13 VARIATION OF HEAT TRANSMISSION WITH AIR

deep non-actinic color of the vapor and strong russet red of the condensed films made the processes of diffusion and condensation easy to follow. The final apparatus consisted of a boiler 3 ft. long, 7½ in. in diameter, made of No. 19 B.W.G. galvanized sheet steel with joints folded, soldered and tarred. The leakage was only sufficient to reduce the mercury gage level $\frac{1}{50}$ of an inch in 24 hours. The boiler was heated externally by 60 gas jets each $\frac{1}{8}$ of an inch in diameter.

The boiler was provided with glass windows for observation of the interior and the standard mercury columns, thermometers, etc. The condensing tubes were in two lengths about 3 ft. long, making an effective length of about 6 ft. The external surface exposed to the vapor was exactly 1 sq. ft., external diameter of the tubes about ⅝ in. thickness 0.018 in., sectional area of the inside tube 0.26 sq. in. Tubes were hard drawn brass.

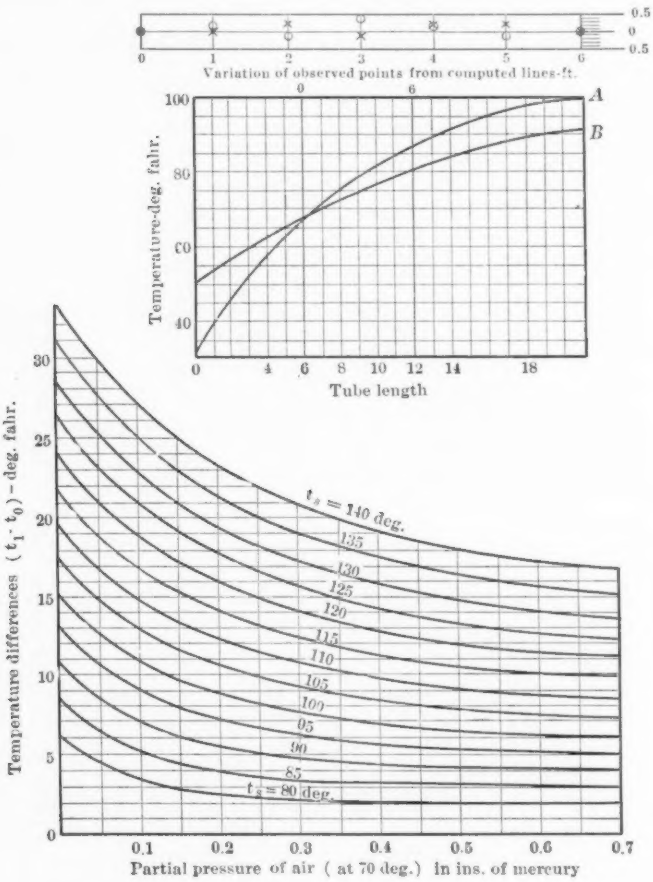


FIG. 14 VARIATION OF HEAT TRANSMISSION WITH AIR

48 Constant-flow apparatus was provided for the condensing water so that various quantities from 2½ lb. to 20 lb. per min. could be passed through the tube. Apparatus was provided whereby, after the boiler was freed from air, a known amount of air at a noted pressure and temperature could be added to the contents of the boiler.

TESTS

49 A series of tests run to determine the effect of air admixture. Air-free steam was condensed at vacuums varying from 70 deg. to 140 deg. at 10 deg. intervals. Air was then added in varying quantities and the process repeated. Another set of tests was made in which the condenser was maintained at constant temperature, while air in the mixture was varied at definite intervals. In both series the cooling water flowed at the constant rate of 10

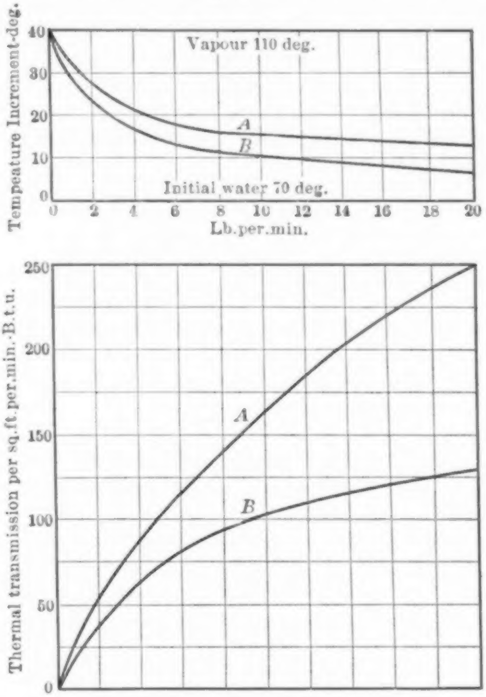


FIG. 15 VARIATION OF HEAT TRANSMISSION WITH WATER VELOCITY

lb. per min. and the cooling surface was 1 sq. ft. From these experiments it was determined that with constant flow and surface and air-free steam the temperature increment of the cooling water is in a constant ratio to the temperature increment of the steam, at least to a first approximation.

50 The presence of air in the condenser, equal in pressure to $\frac{1}{20}$ of an in. of mercury will at 90 deg. fahr. reduce thermal transmission about 25 per cent, while $\frac{3}{20}$ of an in. of mercury of air pressure will reduce the thermal transmission by one-half.

Corollary 1 The rise in water temperature is proportional to the initial steam and water differences of temperatures.

Corollary 2 Each decrement of condenser temperature requires a proportional increment of cooling surface, provided the tube length is constant.

51 Experiments were made to determine the law of the rise of temperature of the cooling water in the tube, and points were taken 1 ft. apart in the 6 ft. of length of tube, making seven points in all. The temperatures observed at these points under various conditions were plotted and found to lie along an exponential curve, the observed points varying no more than 0.4 of one degree from the calculated curve. When air was admitted to the steam the curve was considerably flatter than with air-free steam. From this it is deduced that economy requires the use of relatively short tubes.

52 Experiments were also made to determine the variation of the heat transmission with the rate of flow of the cooling water. These experiments did not go beyond a water velocity of $2\frac{1}{3}$ ft. per sec., but the tubes were small and in all cases the water was probably above the critical velocity. With air-free steam the transmission at 5, 10 and 15 lb. per min. was in the ratio of 1 to 1.64 to 2.10, while with 2.22 in. of air pressure by mercury gage with the same flows the ratios were 1 to 1.31 to 1.52.

AIR PUMPS

53 It is stated that if air is present only to the extent of $\frac{1}{25}$ of an inch of mercury the ratio of the effective volume of the air pump to boiler feed is 20 to 1. The air pump must be separate from the water removing pump. Air pump inlets should be multiplied in number and so situated that the concentrating air in the vapor will pursue the course of shortest contact with the cooling surface; no dead spaces should be possible.

54 The author's conclusions are:

a If high vapor vacua are required air must be excluded.

b With high vacua climatic conditions are limiting factors and must be specially considered.

c In the absence of exact knowledge the impossibility has been attempted in design. Only by rational condenser proportion will it be possible to push the efficient expansion of steam to those limits that recent improvements in motors seem to render easy of attainment.

TESTS BY GUSTAV A. HAGEMANN

Proceedings of Institution of Civil Engineers, Vol. 77, p. 311, 1883

55 The author refers (page 311) to experiments of Messrs. Easton and Amos of London as the only ones published. These were made on a perpendicular iron tube $\frac{1}{16}$ in. thick and $1\frac{1}{2}$ in. diameter, which was enclosed in a larger tube 3 in. diameter, containing water. Dry steam of known temperature was led into the inner pipe and the amount of steam condensed and the rise of temperature of water was measured. By means of this apparatus a temperature difference of 69.5 deg. cent. gave a heat transmission of 15.3 units of heat per unit of area.

56 The author used an improved apparatus as follows: A brass tube 0.0788 in. thick and 1.93 in. outside diameter and 37 in. long, giving a heating surface of 1.56 sq. ft., was fitted steam tight in the center of a strong cast-iron pipe, about 6 in. inside diameter, the lower end of the brass tube being connected by

a pipe with a tank which contained a copper steam coil whereby the water in the tank could be raised to any desired temperature. The other end of the tube connected to a vessel on a scale. The iron pipe was provided with steam through a smaller pipe tapped into it.

$$t_s - \frac{(t_1 + t_2)}{2} = \text{temperature difference, deg. cent.}$$

t_s being steam temperature and t_1 and t_0 water temperature. If A is weight of water passing in B minutes, $\frac{A}{B}(t_0 - t_1)$ = units of heat transmitted per min. in lb., deg. cent.

$$\frac{2\,A\;(t_0 - t_1)}{B\,S\;[2\,t_s - (t_0 - t_1)\,]} = \text{units of heat transmitted per sq. ft.}$$

per deg. cent. per min., where S = internal heating surface.

57 After a few tests the space between the inner and outer tubes was found to be too great giving large variations in the temperature readings; accordingly, a tube 1.515 in. in outside diameter, and closed at both ends was placed in the heating tubes, thus reducing the space for the water to pass to an annular area 0.1305 in. in width.

APPENDIX NO. 3

REFERENCES TO TRANSMISSION OF HEAT THROUGH TUBES PARTICULARLY AS APPLIED TO SURFACE CONDENSATION

1835 Poisson. Theorie Mathematique de la Chaleur.

1846 Bourne. A Treatise on the Steam Engine.

1844 Peclet. Experiments on the Conductivity of Metals. Traite de la Chaleur. *Liege.*

1856 Grashof. Angewandte Mechanik. *Leipzig.*

1860 Wye Williams. Heat and its Relation to Steam and Water. *London.*

1861 Joule. Experiments on Transmission of Heat: (1) Steam to Air. (2) Steam to Water. Phil. Trans. Royal Soc., Vol. 151, p. 133.

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FIRST LARGE GAS-ENGINE INSTALLATION IN AMERICAN STEEL WORKS

By E. P. Coleman

TABLE OF CONTENTS

	PAGE
Introduccion	1837
General Description of Plant	1838
Furnaces	1839
Piping	1840
Gas Washers	1840
Gas Washers Nos. 1 and 2	1841
Gas Washers Nos. 3 and 4	1844
Blowing-Engine Houses	1851
Oiling System	1858
Power House	1858
Koerting Two-Cycle Engines	1859
General Notes Relating to Operation	1872
Gas-Cleaning and Supply System	1873
Lubrication	1876
Ignition	1877
Governing	1879
Cylinders, Pistons, Rods, Valves, Etc	1880
Operating Costs	1883
Observed Quantative Results	1885

LIST OF APPENDICES

No. 1	Investigation to Determine Relation between Point of Ignition and Speed of Rotation	1895
No. 2	Diagram Showing Losses Due to Air and Gas Pumps	1900
No. 3	Data upon Efficiency Trials of 2000-h.p. Blowing Engine	1904

FIRST LARGE GAS-ENGINE INSTALLATION IN AMERICAN STEEL WORKS

DESCRIPTION AND OPERATING CHARACTERISTICS OF SIXTEEN BLOWING-ENGINE UNITS OF 2000 H.P. EACH, EIGHT ELECTRIC-GENERATING UNITS OF 1000 H.P. EACH AND GAS-CLEANING PLANTS

By E. P. Coleman, Buffalo, N. Y.

Member of the Society

At the Buffalo works of the Lackawanna Steel Company is located the first gas-engine power plant to be operated in this country with blast-furnace gas. In the following pages it will be attempted to furnish a description of the plant, certain details of its operation and some data of a quantitative nature derived from observation and operation.[1]

2 As far as can be learned, the selection of the type of engine was made in 1900, based on extended observation of the working of blast furnace gas-power plants by a committee in Europe. The types observed were the Cockerill, Otto, Oechelhaueser, and Koerting. The Oechelhaueser engine was disregarded on account of the crank shaft design and the four-stroke cycle engines were not favorably considered on account of exhaust valve troubles which did not seem to have been mastered at that time. The engines were built by the De La Vergne Machine Company, New York, after designs by the firm of Koerting Brothers, Hanover, Germany.

[1] In the collection and tabulation of various of these data, and other matters, the author begs to acknowledge valuable assistance of the following gentlemen: Hugh Boyd, E. E. Kiger, George Conlee, F. C. Baker, F. L. Palmer, F. C. Taylor, R. L. Streeter and Harry Thompson, all of whom are, or have been, members of the engineering department of the Lackawanna Steel Company. The experience of the author at this plant dates from about the early part of 1906.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

3 At this plant 12,000 to 15,000 net h.p. is normally developed by gas engines operated with blast-furnace gas, the greater portion for blowing the furnaces. There are sixteen blowing engines, each rated at 2000 i.h.p., and eight electric power units, each consisting of a gas engine rated at 1000 i.h.p., direct-connected to a 500-kw. generator. Four of these units generate direct current at 250 volts, and the other four generate three-phase 25-cycle alternating current at 440 volts. All of these gas engines are of the two-stroke cycle type, equipped with twin cylinders and cranks spaced 90 deg. apart. A brief general description of the plant used in developing this power will first be given, followed by a more detailed description of the various parts.

GENERAL DESCRIPTION OF PLANT

4 The general arrangement is shown in plan, Fig. 1. There are six blast furnaces in a line extending approximately north and south. These furnaces are grouped in pairs, each pair forming a unit with reference to the arrangement of its stoves, ore bins, gas plant, and other auxiliaries. A seventh furnace not shown is now in operation, but as all of the excess gas from this furnace is burned under boilers, it does not concern the subject under consideration.

5 The blowing engines using gas are located in the two buildings, No. 2 and No. 3 blowing-engine houses. The engines in blowing-engine house No. 2 furnish air for furnaces 3 and 4. Furnaces 5 and 6 are supplied with air by the engines in blowing-engine house No. 3. The air for furnaces 1 and 2 is usually supplied by steam engines located in the north end of blowing-engine house No. 2. Considerable flexibility is secured by means of cross connections, with valves, between the various cold blast mains. The gas-driven electric-generator units are located in the south end of power house No. 1, situated east of blowing-engine house No. 2.

6 The generation of power at this plant requires three principal processes: the production of the gas by the furnaces; the preparation of the gas for use in the gas engines, involving cooling, cleaning and drying; and the development of power by combustion of the gas in the motor cylinders.

7 The general process of preparing the gas for use in the motor cylinders is as follows: the gas leaving the furnace top passes through large downcomer pipes to the dust catcher, where the heavier portion of the dirt is deposited under the action of gravity. From the dust catcher, portions of the gas pass through pipe mains respectively

to the hot stoves, the boilers, and the gas engines. That portion used by the gas engines is cooled and partially cleaned by means of water sprays in the pipes and chambers through which the gas passes; after which it is further cleaned by passing through centrifugal fans into which water is also sprayed. From the fans the gas passes through separators which remove the entrained moisture and its entrained dirt, and thence under a few ounces of pressure (above atmosphere) to the engine houses. That portion of gas going to the stoves and boilers receives no further cleaning after leaving the dust catcher.

8 There are eight blowing engines in each blowing-engine house, each rated by the makers at 2000 h.p. In the power house are eight engines rated at 1000 h.p. each

FURNACES

9 The six blast furnaces under consideration produce about 2600 long tons of iron per 24 hr. or about 108 tons per hr. The gas amounts to about 150,000 cu. ft. per ton of iron, or say about 16,000,000 cu. ft. per hr. or more from the six furnaces. Approximately 2,500,000 cu. ft. per hr. is used for the gas-engine plant, the remainder being burned in the hot-blast stoves and under the boilers.

10 Furnaces 1 and 2, located at the northern end, are smaller than the others, being rated at about 300 tons each per 24 hr. The main dimensions are: hearth diameter, 11 ft.; diameter of bosh, 17 ft.; height, 87 ft. There are three downcomers of steel plate construction, each 50 in. in diameter and lined with fire brick to 45 in. diameter. These unite at the top of the dust catcher, which is 20 ft. diameter of shell, and equipped with conical top and bottom. The dust catcher is lined to about 18 ft. 3 in. inside diameter and is about 29 ft. deep from inlet opening to dust valve at bottom. These furnaces operate at about their rating of 300 tons each per day.

11 Furnaces 3, 4, 5 and 6 each make about 500 tons of iron per day. Furnaces 3, 4 and 5 are alike in general dimensions. The hearth is 15 ft. 9 in. diameter; bosh, 22 ft. 9 in. diameter; and the height above hearth is 94 ft. Furnace 6 has corresponding diameters of 15 ft. and 22 ft. and is 94 ft. high.

12 Three downcomers of steel plate, each 6 ft. 6 in. in diameter. lined to 5 ft. 9 in. inside diameter, take the gas to the dust catcher, which is 32 ft. in diameter, lined with 9-in. fire brick, equipped with conical top and bottom, and about 39 ft. deep from top gas inlet to dust valve at bottom of hopper.

13 All of the dust catchers are provided with a suspended partition or baffle wall of firebrick cutting off direct passage of gas from inlet to outlet; the gas having to pass under this wall and up to the outlet. The location of these furnaces is shown in Fig. 1.

PIPING

14 The general arrangement and involved main dimensions of the piping for washed gas are shown in Fig. 1. Each group of eight blowing engines is served with washed gas through a 60-in. overhead main of riveted steel plate delivering gas to a main header of 96 in. diameter situated along the wall of the engine house near the yard level. The eight 1000-h.p. engines at power house No. 1 are supplied with gas from furnaces 1 and 2 through a 30-in. underground pipe of cast iron. This 30-in. pipe is cross-connected with the 96-in. header near the south end of blowing-engine house No. 2, by means of a 42-in. overhead pipe. Gas washers 3 and 4 are connected with gas washers 5 and 6 through a 36-in. equalizing pipe as shown. Low points in the piping are provided with drains. The general arrangement of this piping deserves adverse criticism, as will be shown. No gas holders are installed or required. The length of the 30-in. main supplying the power house is about 1180 ft. The 60-in. main supplying engine house No. 2 is about 525 ft. long, and the 96-in. header at blowing-engine house No. 3 is supplied through about 415 ft. of 60-in. pipe. In this main at the south end of the engine house is a 60-in. venturi meter. The blowing-engine house header lies along the east side of the building. It is supported on the concrete work of the exhaust tunnel and is about 400 ft. long. The 8-ft. section is 255 ft. long and is of riveted $\frac{3}{8}$-in. plate. The plates of the 6-ft. portion are $\frac{5}{16}$ in. thick. A 24-in. connection is taken off for each engine on the side nearest the building. Water is drained from the header by means of an inverted siphon. The total length of piping from the washers to the engine houses is about 3800 ft.

GAS WASHERS

15 There is a gas-cleaning plant at each pair of furnaces consisting of chambers equipped with water sprays for cooling the gas and washing out a portion of the dirt, centrifugal fans also provided with water sprays, separators for removing the entrained water, and the necessary valves and piping. Symbolic diagrams, Figs. 2 and 3,

FOLDER No. 1

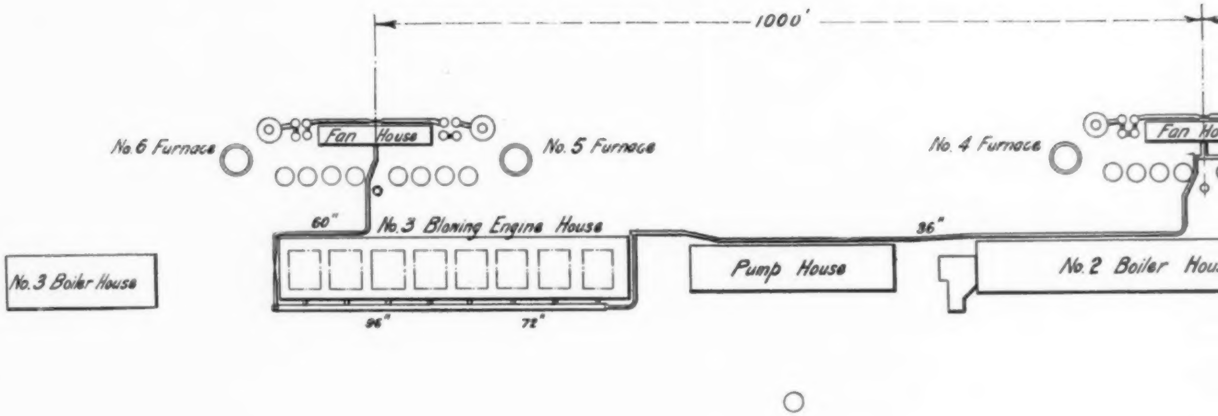
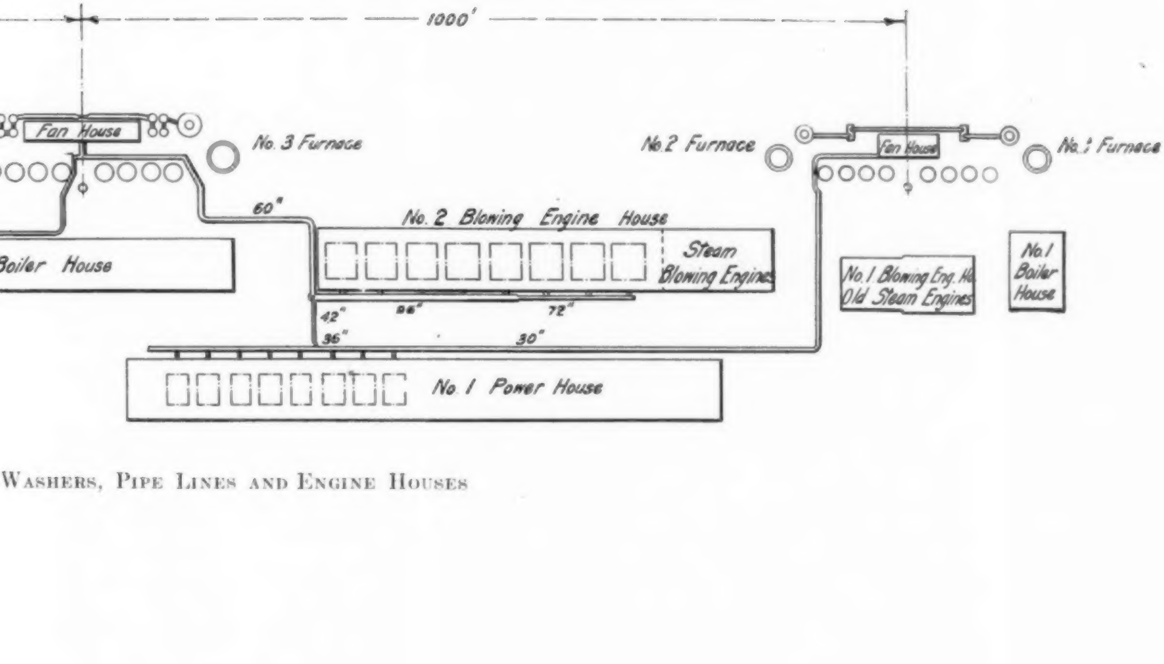


FIG. 1 GENERAL ARRANGEMENT OF FURNACES, WASHERS



Washers, Pipe Lines and Engine Houses

FOLDER No. 2

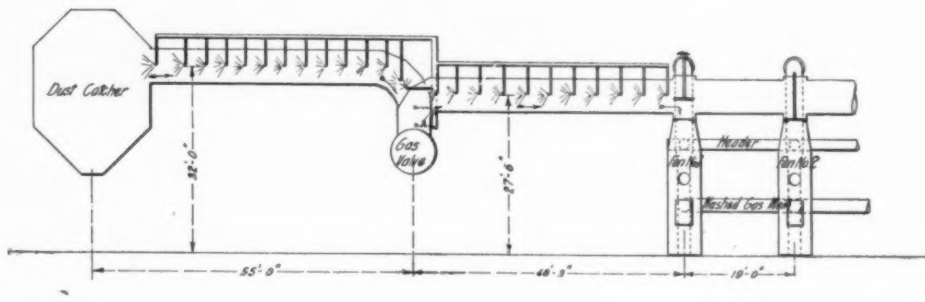


FIG. 2 DIAGRAM OF GAS WASHING PLANT FOR

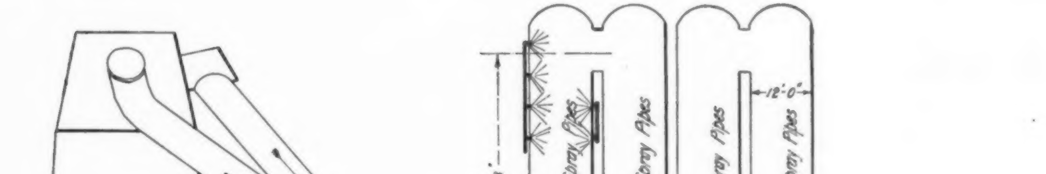
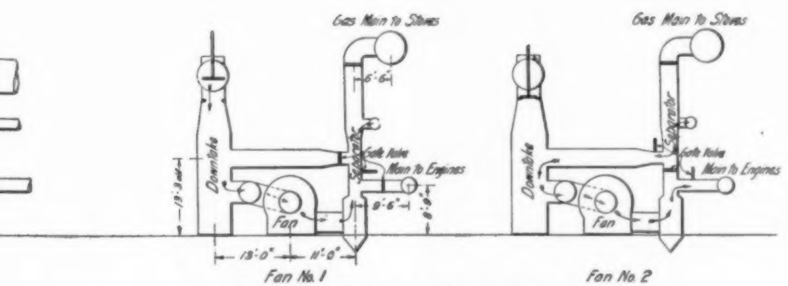
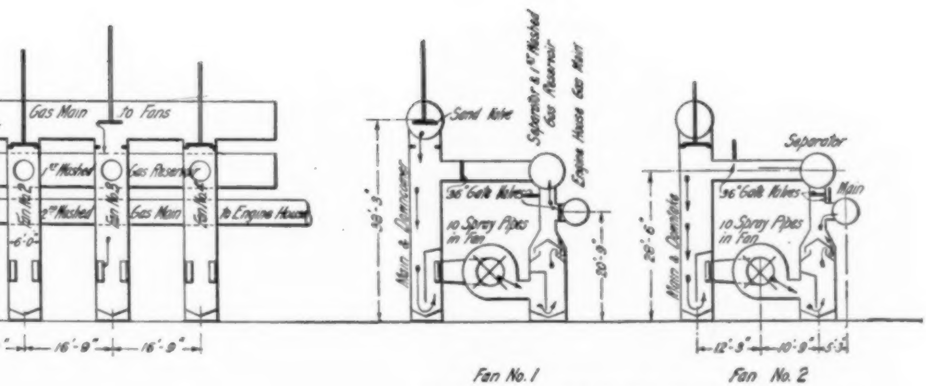


FIG. 3 DIAGRAM OF GAS WASHING PLANT FOR



View Showing Positions of Valves for Operating Fans in Series

LANT FOR FURNACES 1 AND 2



Side Elevations of Fans Nos. 1 & 2 Showing Valve Positions for Operating These Fans in Series

LANT FOR FURNACES 3 AND 4

represent the general scheme. Fig. 2 shows the washery first installed at furnaces 1 and 2. Fig. 3 indicates the arrangement of apparatus at furnaces 3 and 4. The general arrangement of washers at furnaces 5 and 6 is similar to that at furnaces 3 and 4.

GAS WASHERS NOS. 1 AND 2

16 Fig. 2 shows the schematic arrangement of this cleaning plant. Gas is taken from the dust catchers through horizontal pipes where it is given an initial cooling and washing by means of water sprays. The cool gas then passes to four fan washers located between the two furnaces. These fans are normally operated in pairs, each pair forming a unit consisting of the two fans operating in series with each other. The first fan draws cool gas from the main supply and discharges it to a first-washed main. The second fan takes its gas from this main and discharges it to the second-washed main, from which the gas passes to the 30-in. gas line and to the power house.

17 The pipe leading from dust catcher to fans is 70 in. in diameter. At a point about midway between the fans and the dust catcher a water seal valve is located, consisting of a horizontal steel tank 8 ft. in diameter, through which the gas passes on its way to the fans. By filling with water it acts as a shut-off valve and by partly filling with water the gas flow may be reduced to any desired extent, these functions being useful when a furnace is working badly and giving a poor quality of gas. The 8-ft. tank also serves as a receptacle to which the water is drained from the cooling sprays.

18 The 70-in. pipe connecting the dust catchers to the fans is about 236 ft. in length, the total travel of the gas from dust catcher to fan being about 123 ft. Located in this piping are 99 water sprays for cooling the gas on its way to the fan washers. These spray nozzles are located at the axis of the pipe, about 3 ft. 6 in. apart, and discharge a cone-shaped spray into and against the flowing stream of gas. The sprays are supplied from a 3-in. header through 1-in. pipe connections and each spray consumes about 8 gal. of water per min. The water drains first into the 8-ft. tanks and from thence through a seal into tank cars beneath, where the dirt is deposited and the water passes off from an overflow into the general drainage system.

19 The connections to the fans are taken from the bottom of the 70-in. main, the connection being 48 in. in diameter, enlarging to 70 in. diameter. Each connection can be shut off from the gas pipe by means of a disc valve operated by a chain drum and handwheel located

on top of the gas pipe. Each of these connections is provided with a hopper bottom, valve and drain, forming a pocket for the mud and water brought down with the gas. The drain pipe extends downward into a well, forming a seal.

FIG. 4 PIPING AT FURNACES 1 AND 2

20 The four fans are housed in a steel frame building enclosed with corrugated steel sides and roofing and open for light and ventilation on all sides.

21 The fans are very similar in general features to ordinary centrifugal ventilating fans. The wheels are 6 ft. 11 in. in diameter. There are 8 blades, each $15\frac{1}{2}$ in. wide at the inner end and 13 in. wide at the tip, carried on tee-iron arms set in a cast-iron hub. The wheel is split, and the casing of steel plate is arranged for convenient access to and removal of the wheel.

22 The cast-iron suction connections are rectangular. The main is $20\frac{1}{4}$ in. by 52 in. A branch 21 in. by 48 in. leads to each side of the fan, the opening to the fan casing being 36 in. in diameter. These connections are provided with cleaning holes to facilitate removal of mud. Water connections are provided for four nozzles on each side carried through the casing and discharging through the circular inlet to the fan. Waste water from the furnace tuyeres and bosh plates flows from the furnace troughs into a stand pipe equipped with an overflow located at the proper level, and a portion of the water in the stand pipe passes through pipes to the fans.

23 Each fan is driven by a 75-h.p. electric motor direct-connected to the fan by means of a flexible coupling. Three of these motors utilize alternating current and the remaining motor is of the direct-current type. These motors operate at about 500 r.p.m., the input being normally about 55 h.p. each. Control is by means of a switchboard located in a small brick building just outside the fan house.

24 Each fan discharges horizontally at the bottom through a $21\frac{1}{2}$-in. by 45-in. connection into a water separator. The separator is a box of steel plate 4 ft. square by 9 ft. high, containing a set of baffles consisting of 3 rows of 3-in. steel channels, the flanges of the channel bars facing the stream. The openings between channels are about 1 in. wide, and the spacing is alternate or staggered, such that the streams of gas are broken and turned. The separated water and mud drops to the bottom of the separator and passes out through a seal. The gas leaves the separator at the top through a 24-in. pipe connection.

25 First-washed gas which has passed through one fan passes back into one of the 70-in. vertical connections on the cool gas main, and is isolated from it by means of the disc valve at the top, previously mentioned. The gas then flows through the second-wash fan to the second-washed gas main; and thence through the 30-in. line to the power house.

26 The piping and valves are so arranged that any fan may be used for either first or second washing. The valves in the fan connec-

tions are 24-in. Chapman gates, with seats and discs of cast iron. The water valve and pipe main containing the cooling sprays are shown in Fig. 4.

GAS WASHERS NOS. 3 AND 4

27 The gas passes from the dry-dust catcher through a 96-in. connection leading to a set of four cooling towers 12 ft. in diameter and 72 ft. high. The cooling water is sprayed into these towers through numerous nozzles set in the sides. There is a set of towers for each furnace, the two sets being connected by means of an 84-in. header from the bottom of which the fans draw the gas for washing. The first-washed gas passes from the fans through a water separator into a 78-in. header called the first-wash main, from which it is passed back to the suction side of the fans working on second washing, these being shut off from the cooled-gas main. From these fans the gas passes through the separators and into the second-washed main of 60 in. diameter. The 60-in. main supplying the engines is connected to the middle point of this header.

28 The four cooling towers are carried on a structural platform about 30 ft. square and 18½ ft. above yard level. This elevation provides clearance for the mud cars placed beneath to receive the drainage from the bottom connections. The connections between the towers are 8 ft. in diameter and the travel of the gas is up and down in alternate towers. Each tower is provided with a hopper bottom and pipe seal having connection with a common drain pipe which delivers the discharge of all four towers to the tank cars beneath. Towers *A* and *B* are further provided with emergency seal drains at a higher level. These emergency seals are normally idle, but should the bottom drain become clogged the tower will then drain through the emergency seal. Tower *A* is further provided with a suspended steel plate baffle in front of the 96-in. inlet opening. This arrangement when filled with water to the required height acts as a valve to shut off communication between the towers and the dry-dust catcher, a sealed overflow maintaining the proper water level when desired. The first tower is equipped with about 30 sprays, the second has 35, and the third and fourth about 20 to 25 sprays each. The sprays are placed in five circumferential rows, 6 ft. apart vertically. The lower row is about 20 ft. from base of tower. These towers are like those shown in Fig. 5 for furnaces 5 and 6. Several of the illustrations are of the gas washing plant for furnaces 5 and 6 which are similar to that of furnaces 3 and 4.

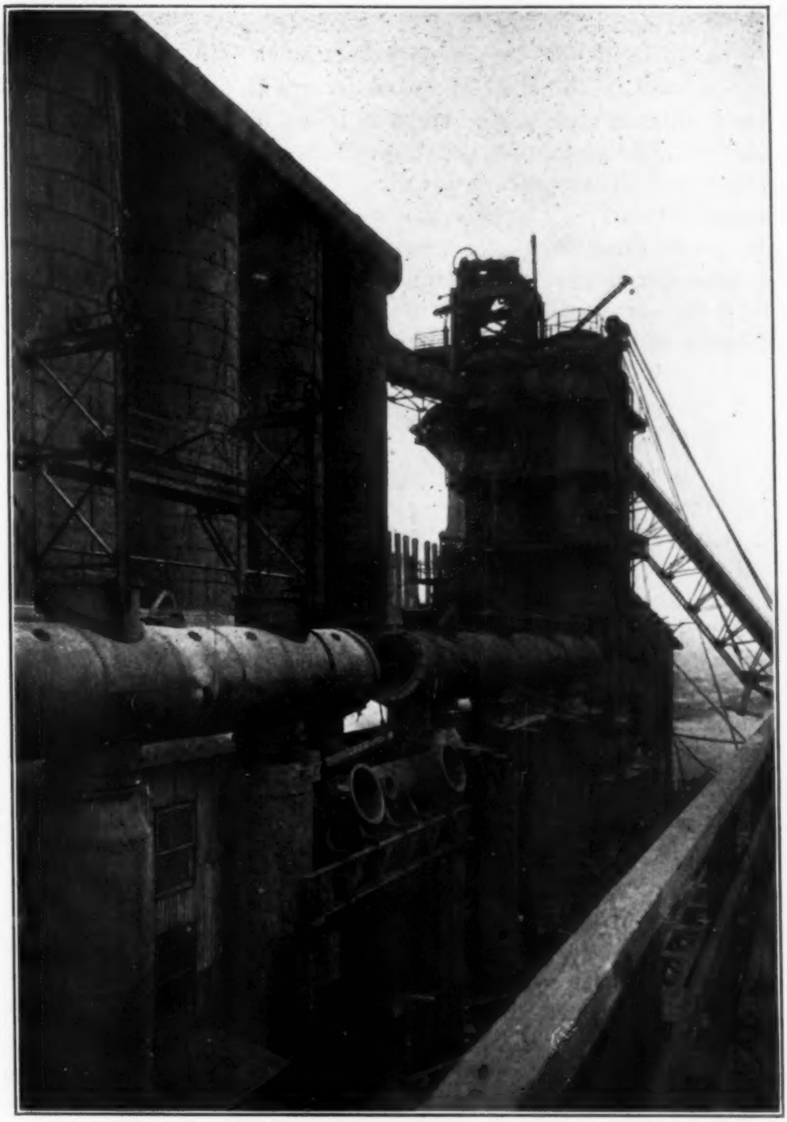


FIG. 5 GAS COOLING TOWERS AT FURNACES 5 AND 6

29 The sprays are supplied with water through three pipes rising from a ring main of 6-in. diameter near the base of the tower. Each spray is supplied through a 1-in. connection provided with a plug cock.

30 The standard nozzle, of brass throughout, is shown in Fig. 6. The shell has a $2\frac{1}{2}$-in. external pipe thread which screws into a flange riveted to the shell of the tower. The helical passage produces a whirling cone-shaped spray of about 90 deg.. and 6 to 10 ft. diameter. The $1\frac{1}{2}$-in. plug provides convenient access to the spindle for cleaning. These sprays use about 7 gal. per min. at the average pressure carried.

31 From the towers the gas passes through a 7-ft. pipe to the fans. This pipe also is provided with nozzles which spray water into and against the approaching stream of gas, the nozzles being located at the center of pipe. The piping is well shown in Fig. 5.

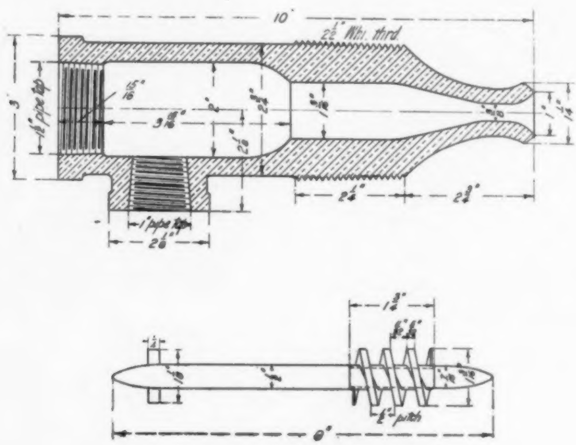


Fig. 6 Details of Spray Nozzle

32 The gas leaves the cooled-gas main at the bottom and passes to the fans through vertical suction connections. The latter have hoppers and water-sealed drains at the lower end and may be shut off from the cooled-gas main by means of bell valves operated by a winch and handwheels located on top of the horizontal main. These valves seat in a water seal. The opening is of 45-in. diameter. At the midpoint of the cooled-gas main connecting the two sets of towers is located a shut-off valve consisting of an inverted siphon which may be partly or wholly filled with water to regulate the amount of gas coming from either furnace.

33 The fan washers are housed in a steel frame building 150 ft. long, 29 ft. wide and 32 ft. high from yard level to eaves, equipped

with pitch roof and monitor, the covering being of corrugated steel. The building and machinery are carried on pile and concrete founda-

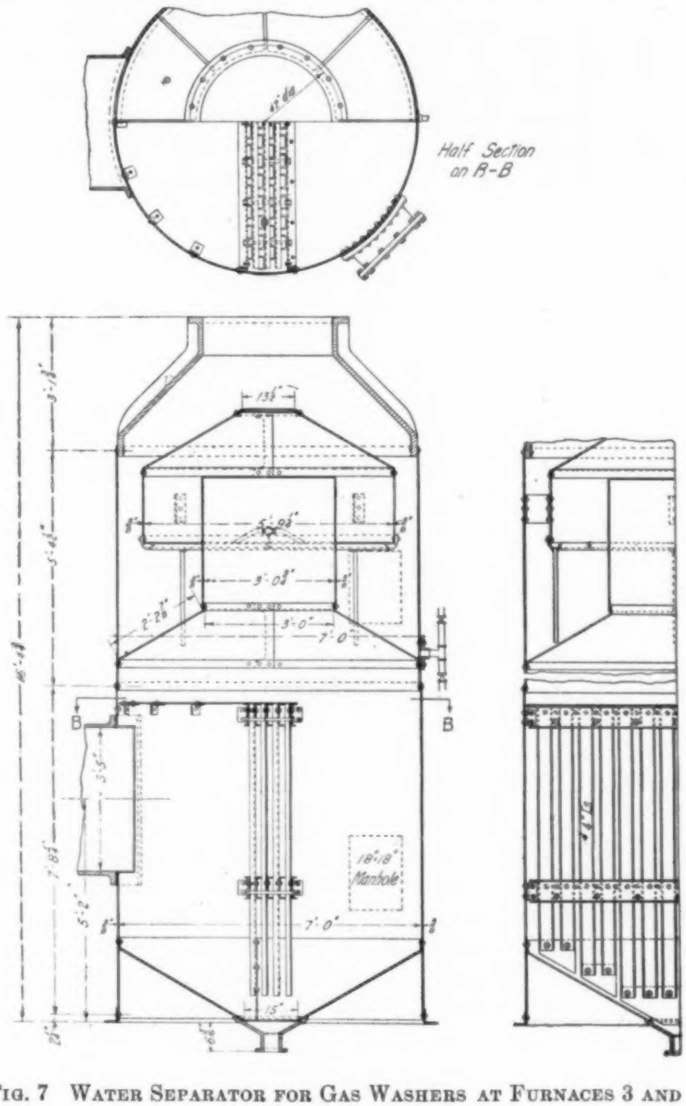


FIG. 7 WATER SEPARATOR FOR GAS WASHERS AT FURNACES 3 AND 4

tions. The center of fan-shafts is 9 ft. 5 in. above yard level, this elevation being necessary for drainage.

34 There are eight centrifugal fans made by the Buffalo Forge Company. The wheels are of $\frac{1}{4}$-in. steel plate, 7 ft. 1 in. in diameter, having eight blades each $29\frac{1}{2}$ in. wide at the inner end, and $27\frac{1}{2}$ in. wide at the tip. Central opening of wheel is 40 in. in diameter.

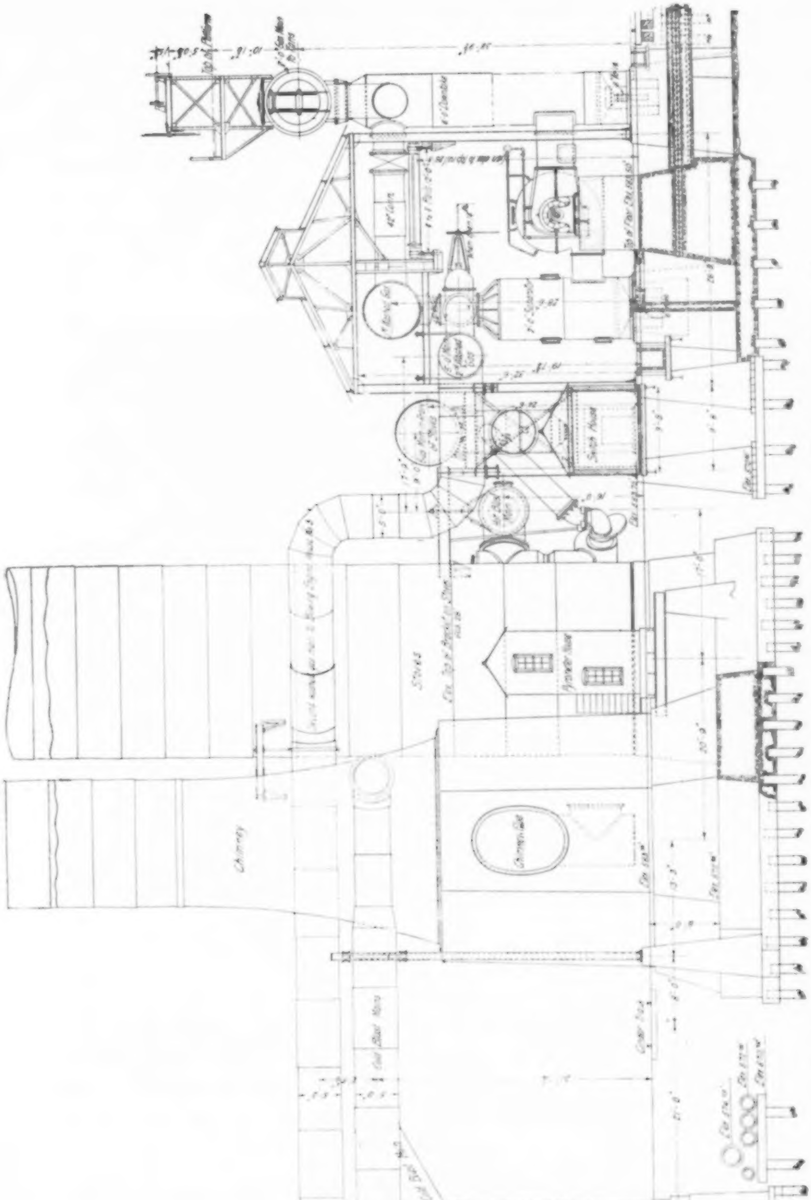
35 The casing is of cast iron and of the double suction type. It is made in sections, with machined joints bolted together for removal of wheel. Manholes are provided for cleaning and inspection. Each branch of the suction connection is rectangular 20 in. by 50 in., opening into the fan through a 36-in. diameter inlet. The bottom discharge connection is 40 in. by 36 in.

36 The wheel shaft of $6\frac{1}{2}$-in. diameter is direct-connected through a flexible coupling to a 100-h.p. motor operating at 480 r.p.m. Six of these motors utilize alternating current, the other two being for direct current. The two types are used so that should there be an accident to either circuit, the motors connected to the remaining circuit will continue to operate and keep a part of the engines running until the necessary corrections can be made.

37 Water is thrown into each fan through 16 spray nozzles. Eight of these discharge into the central inlet openings, four on each side; the other eight dischage into the fan through the upper half of its periphery. The sprays are fed by four $1\frac{1}{2}$-in. lines connected to a 6-in. header extending the full length of the building, over the fans. Each spray connection is a $\frac{3}{4}$-in. pipe. The water for the fan sprays is taken from the waste of bosh cooling water from the furnace, which overflows from a standpipe, a portion under the necessary head going to the fans.

38 From the fan the gas passes to a water separator constructed of steel plate 7 ft. in diameter by 13 ft. high. This separator is shown in Fig. 7. The gas passes first through a set of baffles consisting of four rows of 4-in. channels set vertically, the openings between the channels being $1\frac{1}{2}$-in. wide, with alternate or staggered spacing such that the streams of gas are broken and turned. The separated water falls down the vertical channels, carrying with it the dirt, and passes out at the bottom through a seal to the drainage system. After passing through the channel baffle, the gas rises through annular disc baffles and passes from the separator through a 36-in. top connection.

39 Each separator is equipped at the top with a cast-iron tee providing outlets through 36-in. gate valves respectively to first-washed and second-washed mains. Fans working on first washing discharge their gas into the first-washed main. This gas is then



General Arrangement Elevation of Gas Washers for Furnaces 5 and 6

taken by the fans working on second washing and by them discharged into the second-washed main. The diameters of the first- and second-washed mains are 78 in. and 60 in. The first-washed main

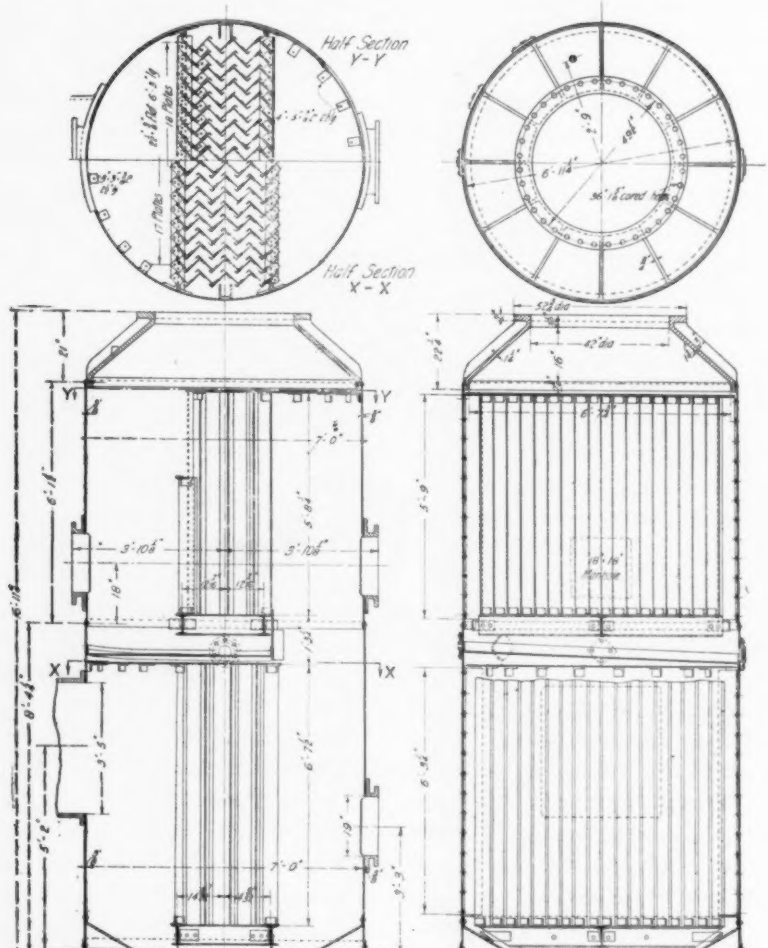


FIG. 9 WATER SEPARATOR FOR GAS WASHERS AT FURNACES 5 AND 6

extends full length of the fan house, and is connected to the vertical suction connection of each fan through a 42-in. gate valve. The valves

and piping are so arranged that any fan may be operated on either first or second washing.

40 These gas washers are shown in sectional elevation in Fig. 8 and Fig. 10 shows the washed-gas main and fan connections in perspective.

41 The gas washing plant at furnaces 5 and 6 is substantially the same as that described for furnaces 3 and 4. The water separators have a different style of baffling. These separators are shown in Fig. 9. They are 7 ft. in diameter and 17 ft. high. The gas circulates through zigzag passages formed by narrow plates assembled as shown.

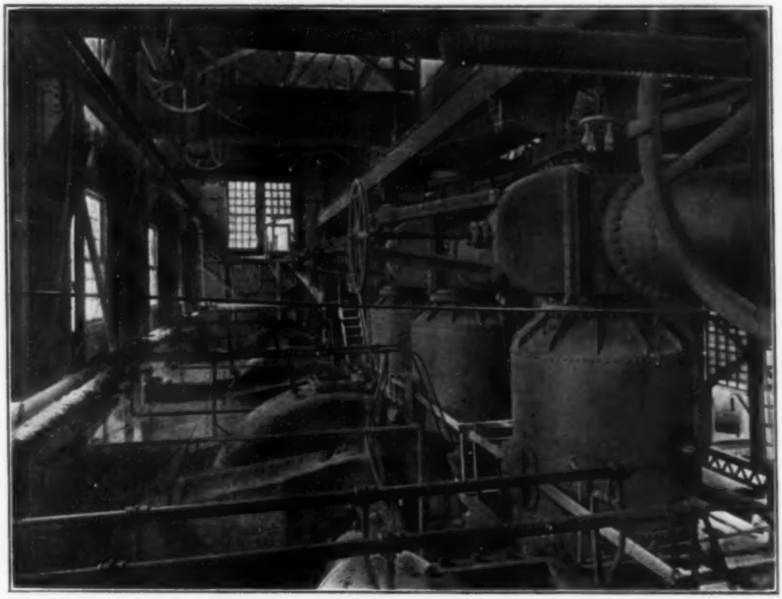


FIG. 10 NO. 5 GAS WASHER FANS AND PIPING

The projecting edges of plates are formed to catch the water and lead it to the bottom of the chamber, where it passes out through a seal. There are two sets of baffles through which the gas passes in succession, one at the bottom and one at the top.

BLOWING-ENGINE HOUSES

42 As previously stated the blowing engines are located in two buildings, blowing-engine house No. 2 and No. 3, each substantially

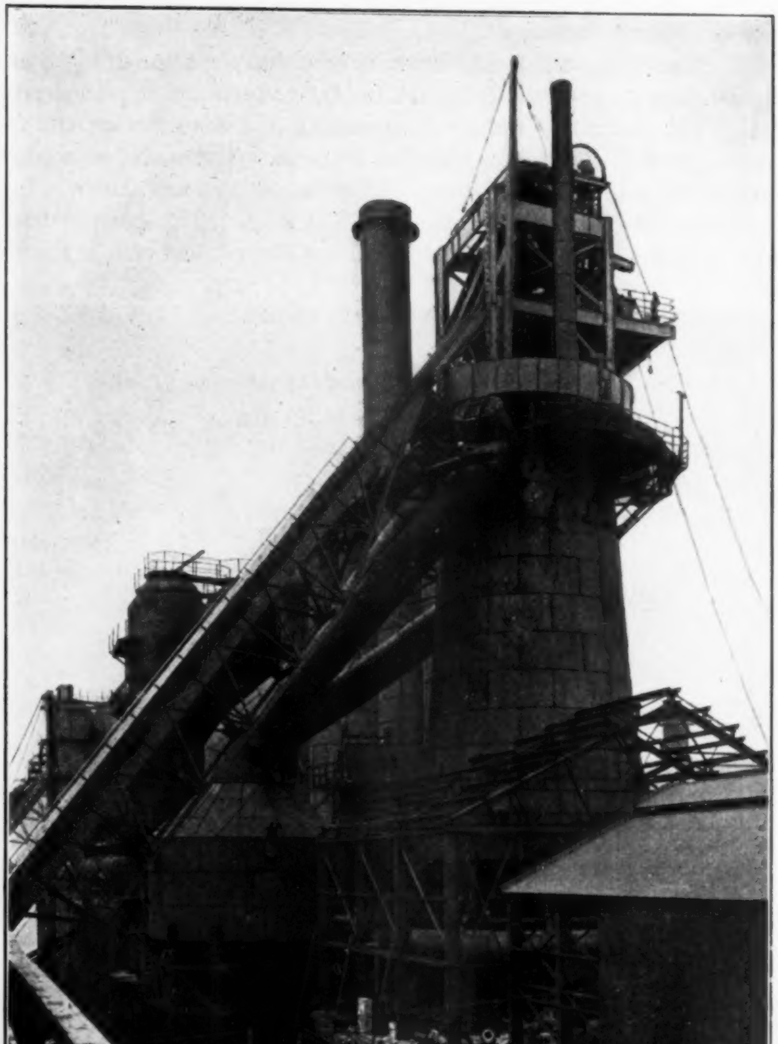


FIG. 11 BLAST FURNACE No. 6

alike in design and arrangement. Each blowing-engine house contains eight air-compressing units (Fig. 13), each unit having a capacity of about 20,000 cu. ft. of free air per min. when operating at 65 r.p.m.

43 The gas engines, built by the De La Vergne Machine Company of New York, are coupled to vertical blowing engines, built by the Southwark Foundry and Machine Company of Philadelphia.

44 Each building is 425 ft. long. A basement 10 ft. deep provides space for piping, oiling system, etc. A steel skeleton frame supports the roof and runways for a 35-ton electric traveling crane. The walls are of brick, and the roof of corrugated iron sheathed inside with wood. Air enters through louvers located in the east wall at intervals of $12\frac{1}{2}$ ft. The flooring is of $\frac{5}{16}$-in. checkered steel plate laid on 10-in. beams. Two cold-blast mains, one for each furnace, extend the entire length of building, and arrangements are such that any of the eight engines can deliver to either of the two cold-blast mains. The piping is so arranged that the north engine in blowing-engine house No. 2 can deliver to furnaces 1, 2, or 7. There is also an auxiliary blast main connecting blowing-engine houses Nos. 2 and 3 in such manner that steam-driven blowing engines may deliver to any one of the seven furnaces, when required.

45 The exhaust gases, jacket water, etc., are discharged into an underground tunnel or header located about twelve or fifteen feet east of the building and parallel to it. This tunnel is provided with two outlets, one into the general drainage conduit, and the other to the atmosphere through a brick-lined steel stack located at mid-point of exhaust tunnel. The exhaust tunnel is also provided with sixteen laterals, one opposite each engine cylinder, and extending only to the outer surface of the concrete foundation wall of the building. These details are shown in Fig. 12.

46 The tunnels are of horse-shoe section of reinforced concrete, supported on piling. The main tunnel is 10 ft. 2 in. high, 6 ft. wide at the bottom, with a semicircular roof 8 ft. in diameter. The eight laterals are about 8 ft. 2 in. high and 4 ft. wide.

47 The ventilating stack is 10 ft. diameter of steel plate lined with red brick to 9 ft. 2 in. diameter.

48 Located between the discharge chamber of each blowing cylinder and the cold-blast main, is a non-return valve. The discharge chamber may be connected to the atmosphere through a pipe extending through the building wall and controlled by a gate valve. This atmospheric connection is opened when it is necessary to start with

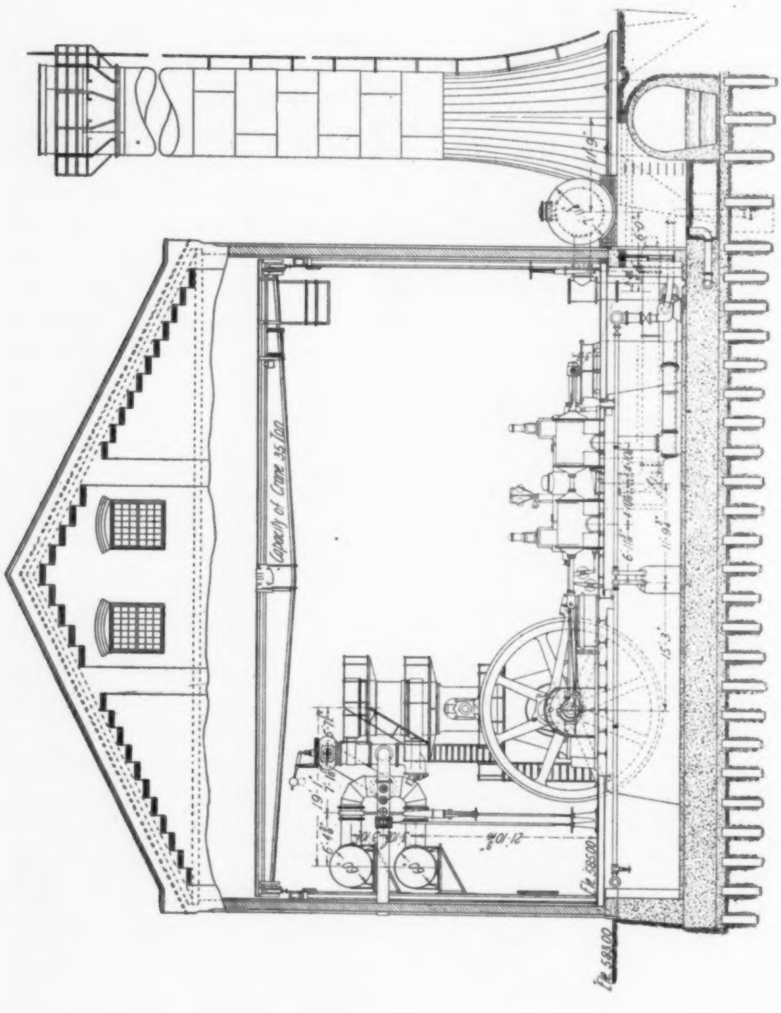


FIG. 12 GENERAL ARRANGEMENT OF BLOWING ENGINE-HOUSE NO. 2

compressed air. When operating conditions have been established in the motor cylinders, the gate valve is closed and the non-return valve rises from its seat for delivery into the blast main.

49 Gas is delivered to each engine from the main header located outside the building through a 24-in. branch, including a standard 24-in. gate valve just inside the building wall and above floor level. The 24-in. pipe then turns downward to the basement floor where it divides into two 18-in. branches, one to each gas pump. The air pumps draw their supply from the basement through short connections passing through the floor.

50 The cast-iron exhaust pipe for each cylinder is 22 in. in diameter. It is attached to the bottom of the cylinder, descends vertically about six feet and then extends horizontally to the east wall of the building and into the lateral tunnel above noted. A tee outlet or double discharge is furnished on the end of each exhaust pipe. A gate valve is provided.

51 During operation water is injected into each exhaust pipe through spray pipes located just below the cylinder. This keeps the pipe cool, partially muffles the exhaust, and prevents explosions in the exhaust piping.

52 The cooling water for the engines is taken from a 12-in. main extending the full length of the building on the east side of the basement. A 10-in. reserve main is installed on the west side. Opposite each engine is located an 8-in. connection with valve. From this connection a 6-in. branch leads to each side of the engine. The supply of water for each engine is thus controlled by one valve.

53 As originally installed, cylinders, pistons and muffling sprays were all supplied with water through individual connections, each wasting to a sewer. The system has since been modified such that the water passes through piston, cylinder heads, cylinder jackets and muffling sprays in the order named. A small portion of the water only is used by the muffling sprays.

54 Thermometers are placed to indicate the temperatures of water leaving the piston and cylinder jackets. The jacket water leaving each cylinder head discharges upward through a vertical pipe provided with a return-bend discharge nozzle. The water leaving the nozzle discharges downward into a funnel leading to the cylinder jacket, the stream thus being in full view of the operator.

55 Compressed air for starting is supplied through a 5-in. branch from a 6-in. main delivering air from power house No. 1. The 5-in. connection divides into two $3\frac{1}{2}$-in. branches, one to each side of the engine where it connects with the starting valve.

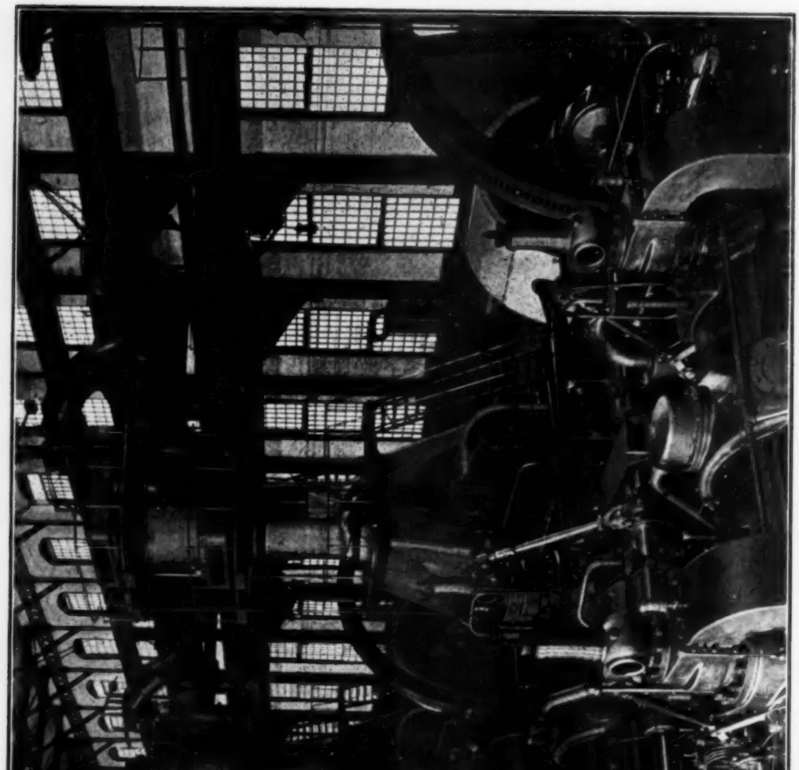


FIG. 13 INTERIOR VIEW OF BLOWING-ENGINE HOUSE

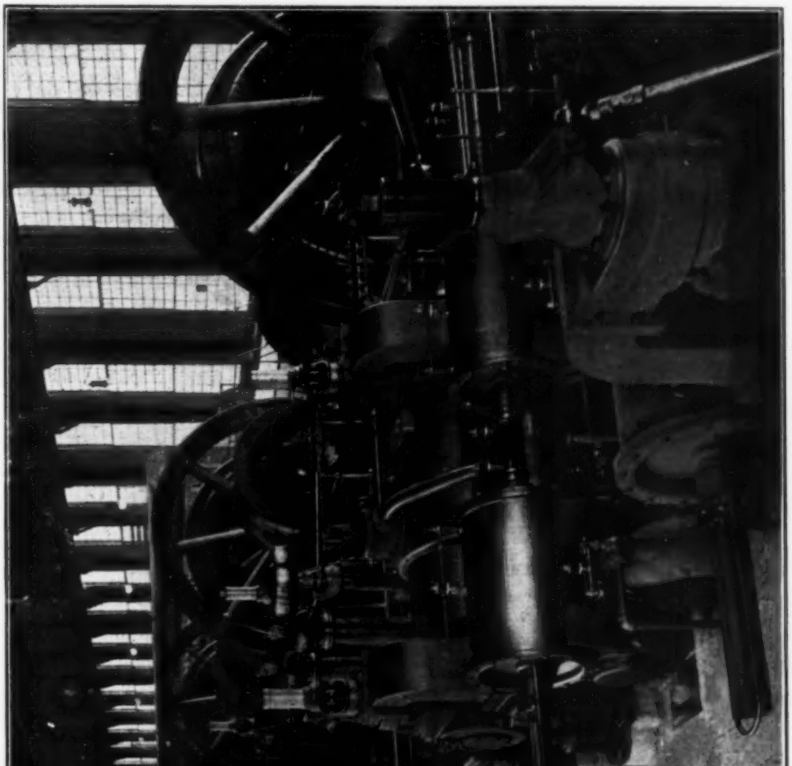


FIG. 14 INTERIOR VIEW OF POWER HOUSE

OILING SYSTEM

56 An oiling system of the gravity type is installed at each blowing-engine house. Two 500-gal. storage tanks are located near the roof from which the oil is piped to the sight-feed connections on the engines. A complete system of drip pans and oil catchers is provided at the engines. From the pans the oil drains to the basement, and passes first through a gravity separating tank where most of the water is removed. The oil then flows over a heating device where its temperature is raised to about 120 deg. fahr. and it then passes through settling tanks and weir boxes, where the remaining water and nearly all of the suspended matter are deposited under the action of gravity. From the weir boxes the oil passes into White Star filters, and thence by means of a duplex steam pump to the storage tanks located near the roof.

57 The above description applies to the system used for supplying oil to parts of the engine where the oil is but slightly contaminated by foreign matter. At certain other points of lubrication, such as the gas pump and motor piston rods, etc., the return oil is contaminated to a considerable degree by flue dirt. A separate system very similar in principal to the one already described is installed to take care of these parts.

58 The buildings are heated by means of the forced circulation of hot water through radiation piping. The piping extends entirely around the building and the water which is heated by exhaust steam, is circulated by means of a centrifugal pump.

POWER HOUSE

59 Eight units for developing electric power, each rated at 1000 i.h.p., are located at the south end of power house No. 1 and occupy a space 350 ft. long. The engines are direct connected to 500-kw. generators, four of direct current, 250 volts, and four of three-phase 25-cycle alternating current, 440 volts. The total length of the building is 725 ft., the width 77 ft. and the height from the floor line to the bottom chord of the roof truss 35 ft. A steel skeleton frame supports the roof and crane runways. A basement 8 ft. deep is provided and a concrete matte, on piling 83 ft. wide by $4\frac{1}{2}$ ft. thick, supports the building and machinery. An interior view of the power house is shown in Fig. 14.

60 The floor is of concrete reinforced with expanded metal, resting on I-beams. Cast-iron gratings between the engines ventilate the basement.

61 The switchboard is placed on a platform 213 ft. long at the east side of the building. A controlling panel is provided for each generating unit. Numerous feeder panels control the various mill circuits. The alternating-current switches are located at the south end of the board, and the direct-circuit control at the north end.

62 The engines exhaust into the main drainage tunnel and a steel stack 5 ft. in diameter and 60 ft. high carries away the gases and vapor.

63 Each engine takes gas from a 30-in. main outside the west wall of the building through an 18-in. connection controlled by a gate valve; this 18-in. connection divides into two branches, one going to each gas pump. A throttle valve controlled by a Tolle governor and placed as close as possible to the valve chest of its respective gas pump, is located in each of these branches.

64 The air pump draws its supply from the basement. Compressed air for starting is provided through a 6-in. main extending the entire length of the plant. There is a 4-in. branch at each engine.

65 The cooling water is supplied from the general yard service through a 6-in. main with branches at each engine.

66 Each motor cylinder is provided with a separate exhaust pipe of 16-in. diameter exhausting directly into the tunnel. Water is sprayed into the pipe to cool and muffle the exhaust.

KOERTING TWO-STROKE CYCLE ENGINES

67 The engines were designed by the firm of Koerting Brothers, Hanover, Germany, and were built by the De La Vergne Machine Company, New York. They are of the two-stroke cycle double-acting twin cylinder type.

68 The blowing-engine units have motor cylinders $38\frac{1}{2}$ in. in diameter by 60-in. stroke, and occupy a floor space of 40 ft. by 52 ft. The engines for electric generating have cylinders $24\frac{3}{4}$ in. in diameter by $43\frac{3}{8}$-in. stroke and occupy a floor space of 32 ft. by 36 ft.

69 The cycle of operation with reference to the motor cylinder is as follows: Gas and air are compressed in separate pump cylinders to a pressure of about 10 lb. per sq. in. above atmosphere. The gas and air meet in the mixing chamber above the inlet valve of the

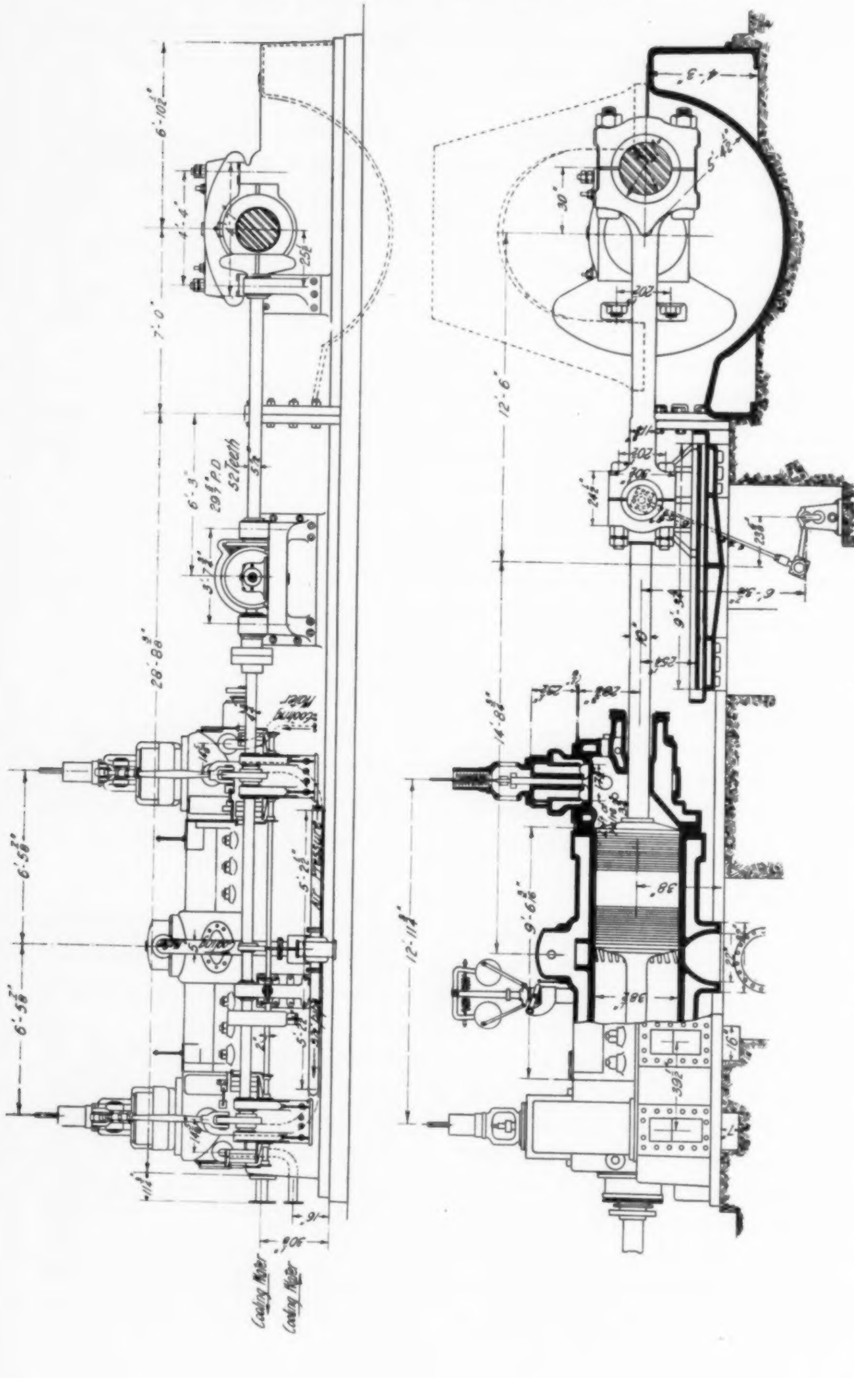


Fig. 15a General Assembly Elevation of 2000-h. p. Engines

motor cylinder. During the period when the motor piston is at and near the outer end of its stroke, the inlet valve opens, admitting first the scavenging air and second the mixture to the motor cylinder. During the return stroke of the piston the charge is compressed to a final pressure of about 150 lb. gage.

70 Ignition by electric spark takes place somewhat prior to the completion of the compression stroke. Near the end of the expansion stroke, the piston uncovers the exhaust ports through the cylinder walls. The opening of the inlet valve occurs very soon thereafter, and the new incoming charge forces the burned gases out through the exhaust ports completing the cycle.

71 The general plan and elevation of the 2000-h.p. engine is shown by assembly drawings in Fig. 15*a* and Fig. 15*b*. The smaller engines are very similar in general design.

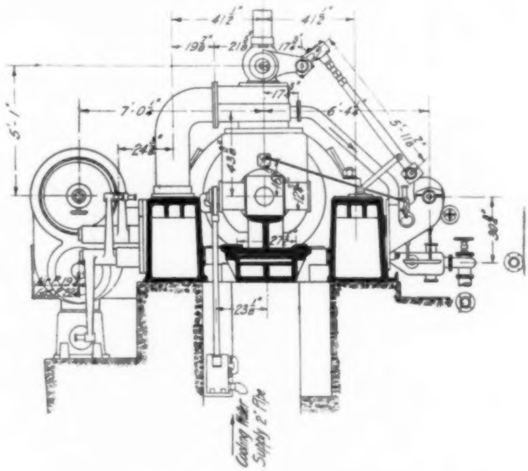


Fig. 15*b* End Elevation of 2000-h.p. Engine

72 Each unit is composed of two separate engines each complete in itself with the exception that the crankshaft is common to both.

73 The main frame for each side is composed of two heavy cast-iron box girders. The motor cylinder is supported on and between these at one end. The shaft bearings are formed in the other end of the frame.

74 At one side are the gas and air pump cylinders. The two pistons are mounted on a single piston rod and driven by an overhung crank on the outer end of the crankshaft.

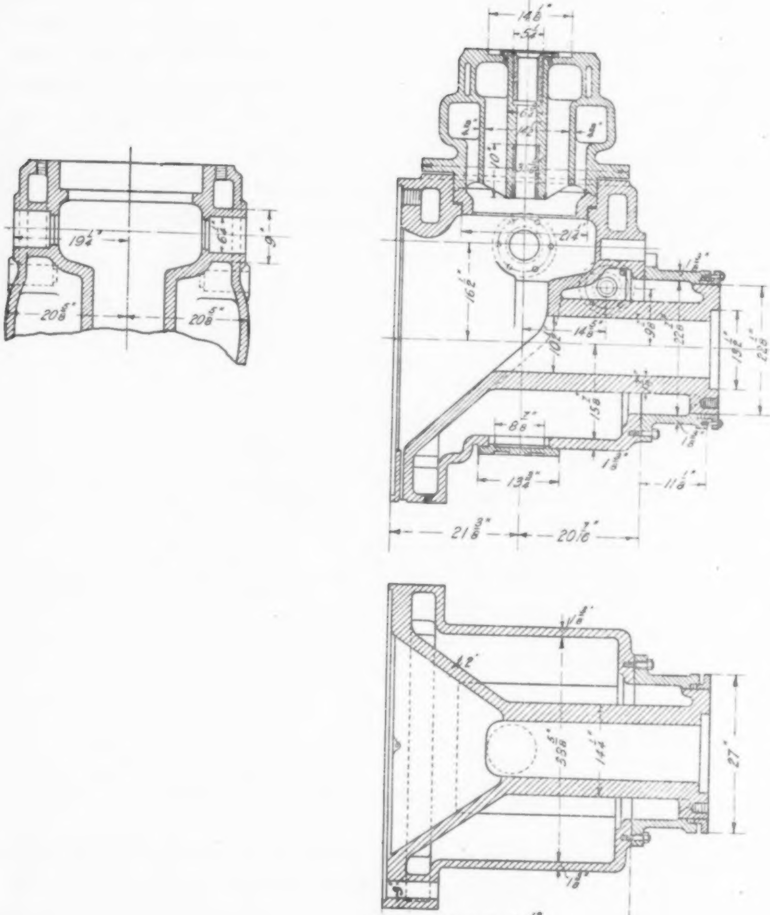


FIG. 16 DETAILS OF CYLINDER HEADS AND INLET PORTS

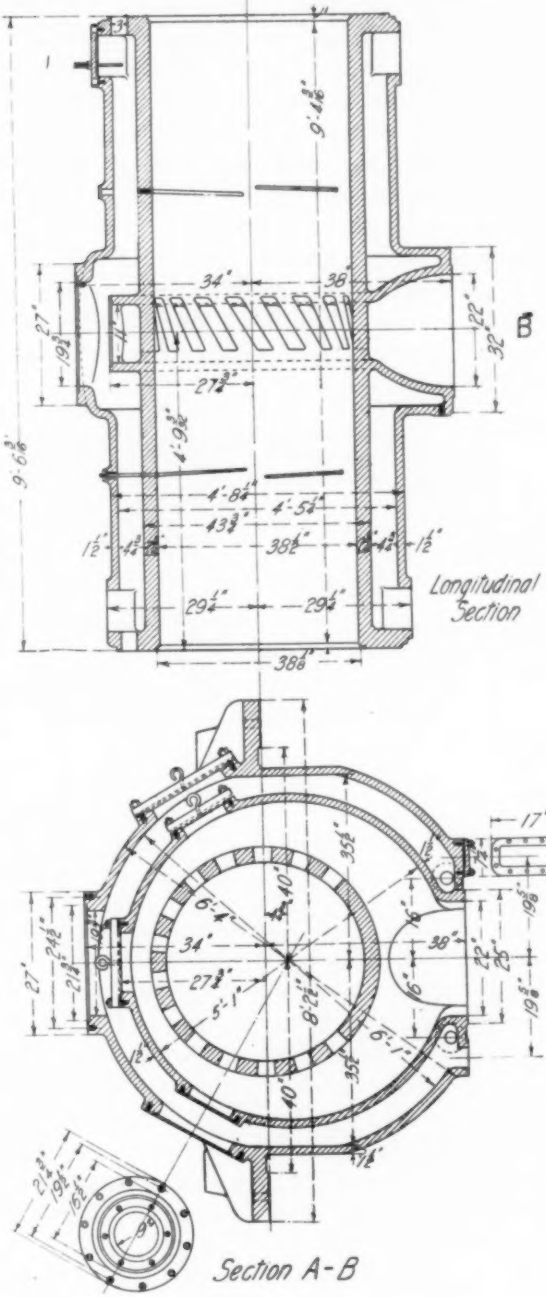


FIG. 17 DETAILS OF MOTOR CYLINDER

75 The pump valves are of the piston type, smooth cylinders without packing of any kind, and are driven by eccentrics on the crankshaft. The induction valve for the gas pump is open during about 145 per cent of its suction stroke; that is to say, during the entire suction stroke as well as the first 45 per cent of the discharge stroke. The air pump discharges during nearly its entire stroke, the object being to provide scavenging air for the motor cylinder prior to the entrance of the mixture. The gas and air pass from their respective pumps through ducts to a mixing chamber above the motor inlet valve. The prior discharge action of the air is intended to force the gas column back into its duct, prior to the opening of the motor inlets, in such manner that scavenging air is provided in advance of the mixture.

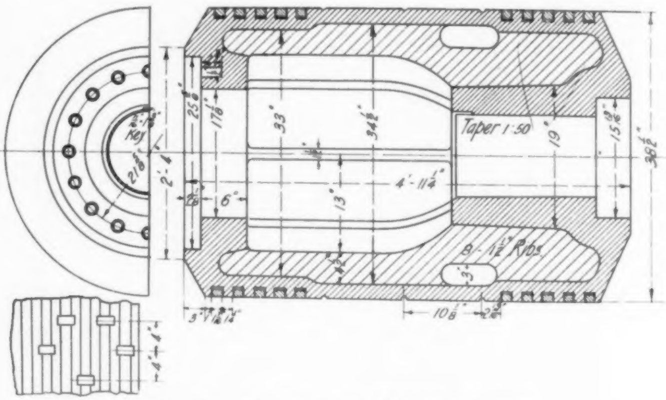


Fig. 18 Details of Motor Piston

76 The motor cylinders are of cast iron in one piece with water jacket and exhaust passage. The cylinder heads (Fig. 16) are of cast iron with water jackets and are provided with an expansion joint. Fig. 17 shows a 38½-in. motor cylinder in detail.

77 The piston is of cast iron, nearly as long as the stroke because of its action as an exhaust valve. Five grooves are provided at each end, equipped with dowells in such manner that the five snap rings are held with their openings near the bottom of the cylinder. The piston (Fig. 18) resting on the cylinder wall closes the opening through the ring and prevents leakage and possibly premature ignitions. Cooling water is supplied through the hollow rod by means of swinging connections shown in Fig. 19.

78 The crosshead is of the slipper type babbitt faced. The marine type connecting rods are forked at the crosshead end. Bear

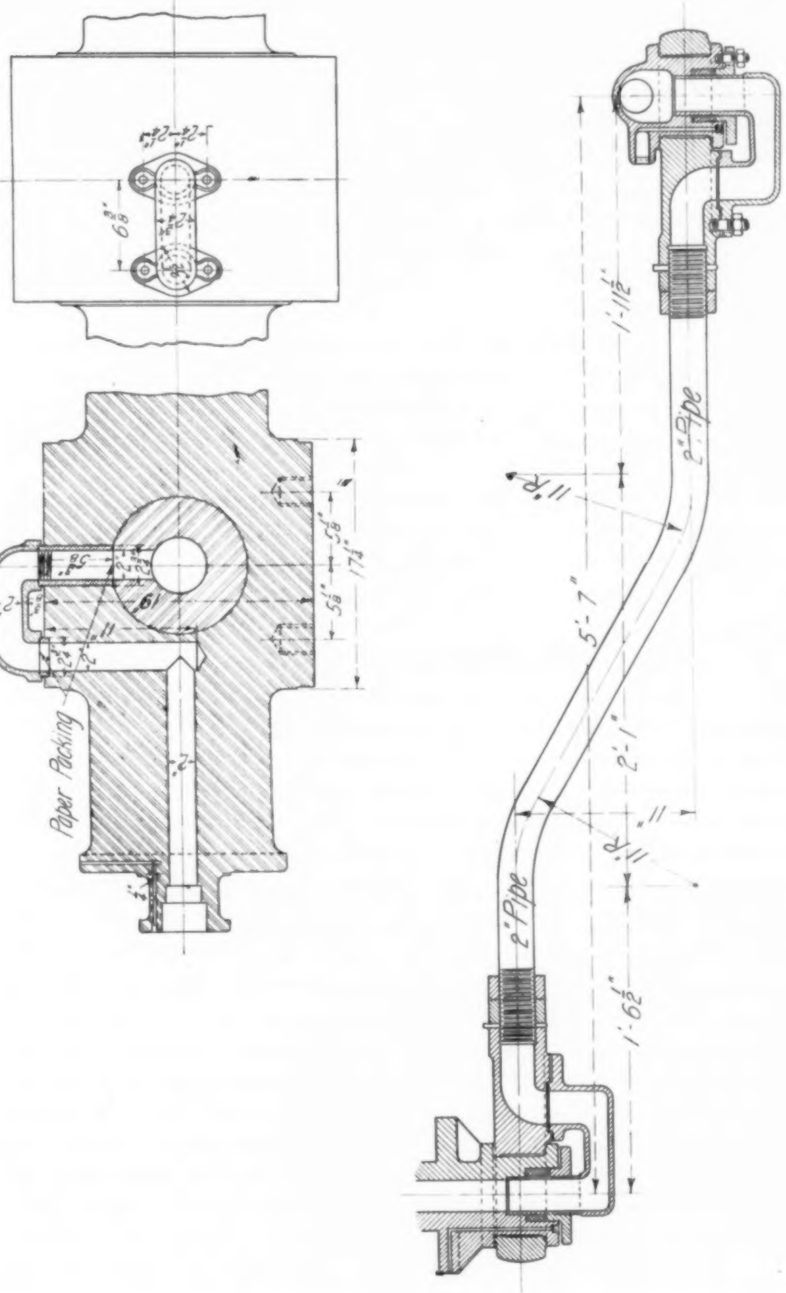


Fig. 19 Details of Water Connection for Piston Rod

ings are split shells, babbitt lined for the crank and phosphor bronze for the crossheads, held by bolted caps.

79 The crankshaft for the 2000-h.p. engine is of the built-up type and is carried by four bearings. Each crank pin is carried by two forged steel webs between its pair of main bearings and to these webs are bolted the counterweights. Each end of the shaft projects beyond its outboard bearing and carries a crank and eccentrics for the gas and air pumps. The shaft for the 1000-h.p. engine is a single forging, being in other respects similar to that for the 2000-h.p. engine. All of the principal forgings were made at the Krupp works in Germany.

80 The flywheels for the 1000 h.p. engines are $17\frac{1}{2}$ ft. 'n diameter and weigh 45,000 lb. The wheels for the 2000-h.p. engine are of 20 ft. diameter and weigh 65,000 lb. The wheels were cast in halves, and the fastenings are steel links shrunk into place at the rim and bolts at the hub.

81 The inlet valves are steel forgings of the mushroom type located in casings at the top of the cylinder heads. They are opened by cams located on a shaft parallel to the axis of the motor cylinder and driven by bevel gears from the crank shaft, and closed by strong helical springs.

82 Ignition is by means of electric spark of the break or arc type, with two igniter plugs in each cylinder head. The electric current is furnished by magnetos, one for each plug. The current is produced in the following manner: The magneto armature is first slowly rotated in opposition to the force of a spring through an angle of about 30 deg. from its initial position. It is then released and under the action of the spring executes a rapid return motion or oscillation. During this return motion the igniter terminals are mechanically separated and the arc formed, the motion of the armature being transmitted to the plugs through cranks and reach rods for this purpose. The magnetos are now being discarded in favor of a direct-current system of ignition of simple form.

83 The timing of the ignition is accomplished by means of the igniter shaft connected to the cam shaft through a helically slotted sleeve and a pair of spur gears. By sliding the sleeve along the shaft, the phase of the igniter shaft is advanced or retarded. One of the spur gears is provided with sufficient width of face to accomplish the required range of movement. The sleeve and hub form a triple threaded screw and nut, and have proved very satisfactory in operation. The apparatus is shown in Fig. 20. The equivalent device

furnished by the makers consisted of a single spiral slot and feather which proved defective in wearing qualities.

84 The regulation of the 1000-h.p. units is by a butterfly throttle valve under the control of a Tolle governor. The strength of these governors is about 2000 lb. The throttle valve is located in the gas supply pipe of each pump, as close as possible to the pump.

85 The 2000-h.p. engines are regulated by means of bypass valves located at the gas pumps, and under the direct control of an adjustable-speed oil-pressure governor. Each gas pump, in addition

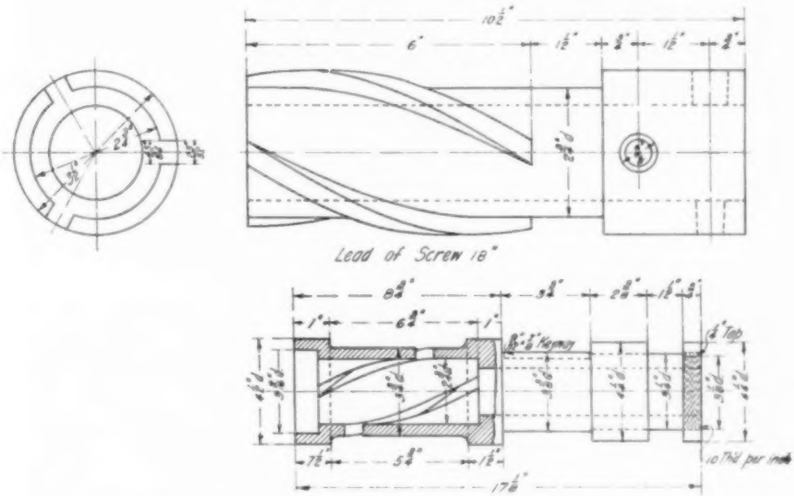


FIG. 20 SCREW AND NUT FOR IGNITER SHAFT

to its original distributing valve, is provided with a reciprocating bypass valve, driven from the pump valve-gear. This valve is of the hollow plug type turned to a working fit in its valve cylinder bushing, and is provided with ports through the walls of the hollow plug. Corresponding ports through the walls of the valve cylinder bushing communicate respectively with A, the gas pump discharge passage, and B, the gas pump clearance. Two respective leakage paths are thus formed through which a portion of the gas is bypassed back into the supply pipe of the gas pump. The hollow plug valve of the bypass is arranged for partial rotation on its axis under control of the governor, and the angular position of the plug valve determines the degree of opening of the bypass ports, which in turn governs the quantity of gas returned to the pump supply pipe. Due to the con-

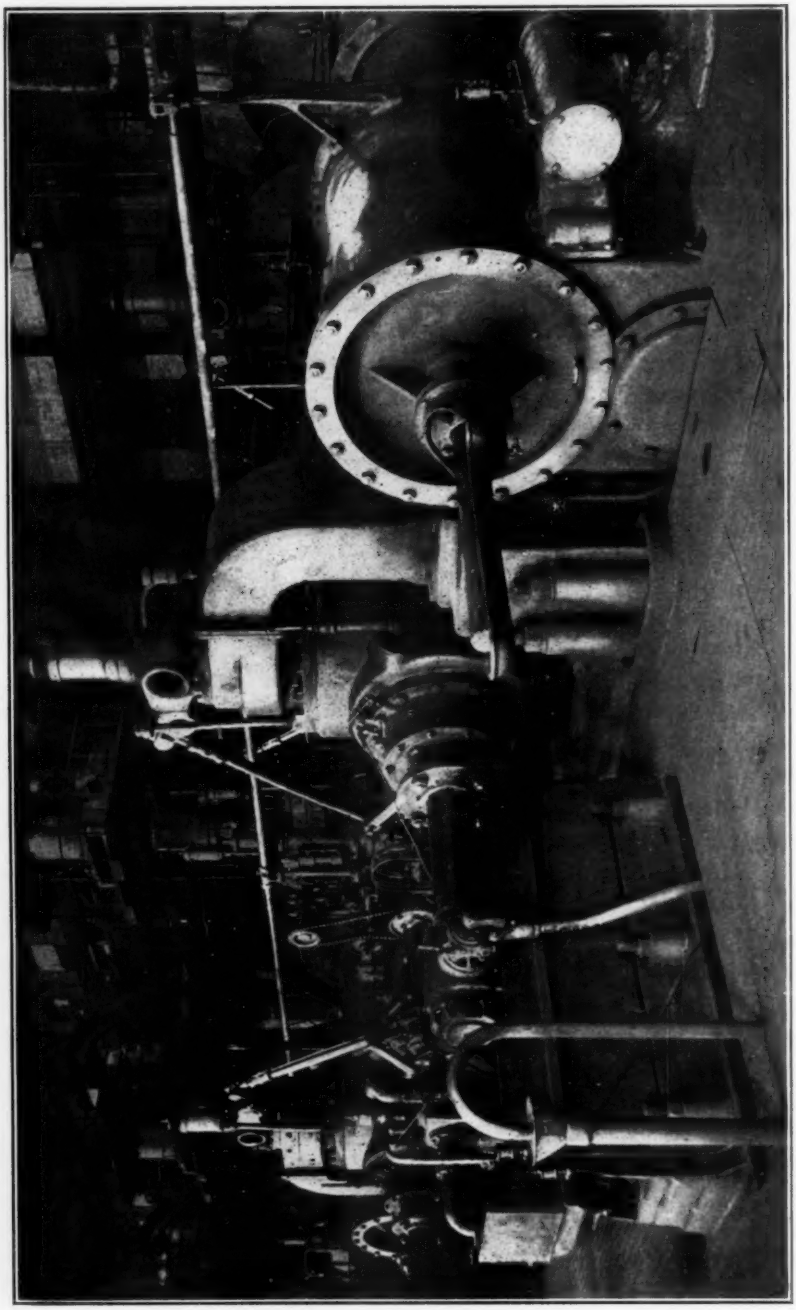


Fig. 21 General View of Governing Apparatus for Blowing Engine

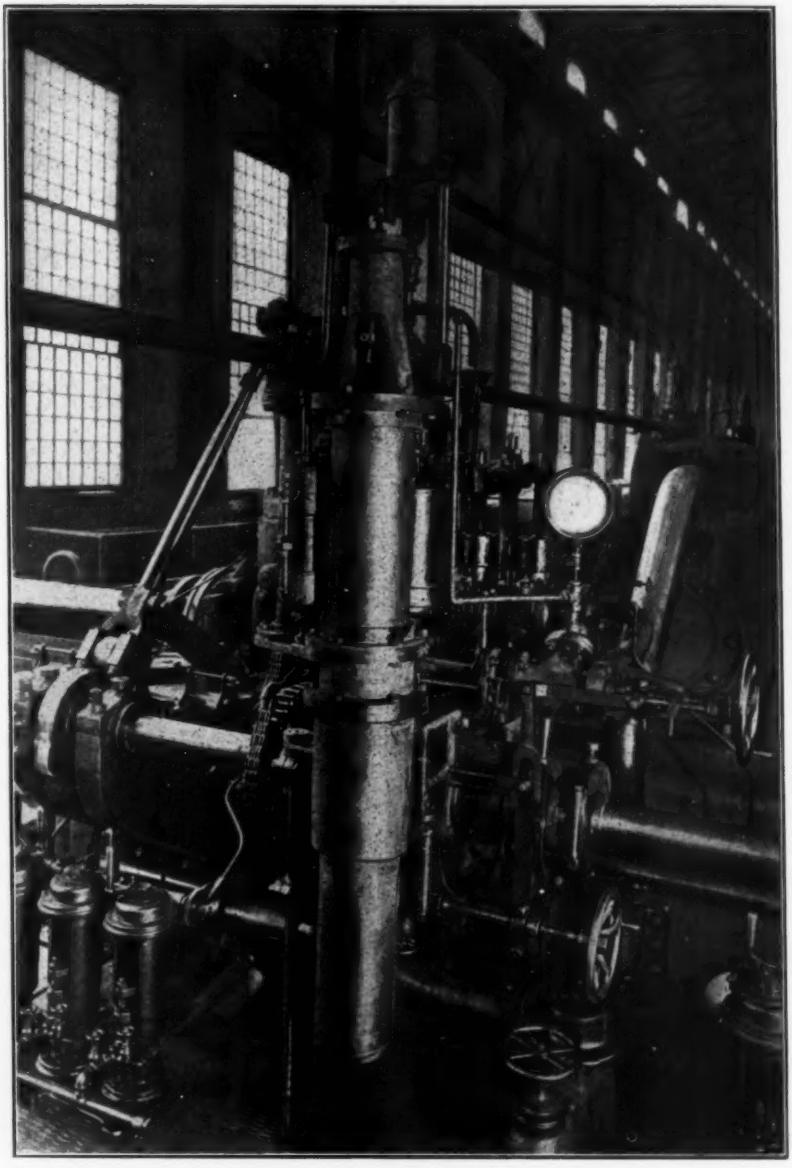


FIG. 22 GENERAL VIEW OF OIL-PRESSURE GOVERNOR

struction of the main pump valve, bypassing from the passage *A* can occur only during the suction stroke of the pump, the bypass port being connected to a chamber which communicates with the pump discharge passage only during such suction stroke. The bypass port from the pump clearance allows bypassing to occur during the discharge stroke of the pump.

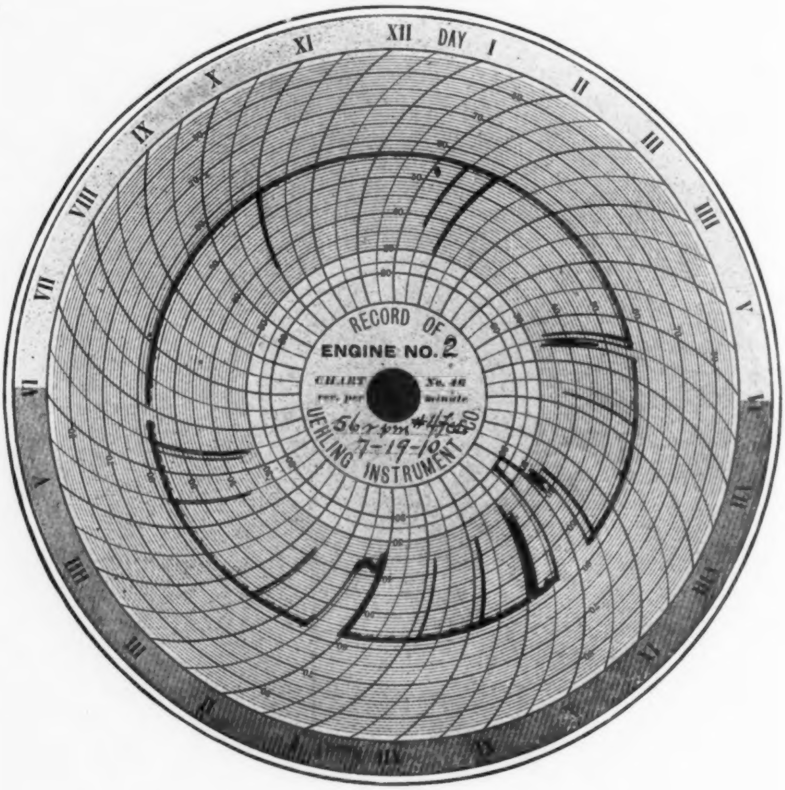


FIG. 23 SPEED CHART—REVOLUTION RECORDER

86 When the governor is in the position corresponding to maximum power demand, both bypass ports are closed. As the demand for power decreases, the port from passage *A* is first opened, the port *B* remaining closed. With a further decrease of power demand port *B* also opens. The port *A* is arranged for prior opening for the purpose of removing the gas from the vicinity of the motor inlet at and

during the scavenging period. The full opening of both bypass ports is sufficient to limit the engine speed to about 45 r.p.m. under conditions of friction load. The reciprocating motion of the valve is provided for the purpose of preventing accumulation of dirt on the valve surfaces, thus preventing any undue resistance to rotation under the action of the governor. The general arrangement of the bypass valve gear is shown in Fig. 21.

87 The governor is of the adjustable-speed oil-pressure type, controlling the valves directly by means of a piston of $4\frac{5}{16}$ in. in diameter operating differentially against the force of a spring. The total tension of the spring is about 830 lb. A $3\frac{3}{4}$-in. by 3-in. single-acting triplex oil pump is driven by means of a 2-in. Renold silent chain from the cam shaft of the engine. The oil is discharged through a $\frac{1}{2}$-in. orifice of special design, the area of which is controlled by a needle valve. The motion of the small piston is transmitted by levers, shafting, and reach rods, and controls the angular position of the bypass valve. The needle valve is linked to the timing device of the igniter mechanism in such manner that the time element or lag of the igniter is neutralized, the ignition remaining constant at all speeds.

88 The speed variation between the extremes of travel is 4 per cent. The energy required to drive the pump amounts to about 0.6 h.p. The valve gear, governor, and timing device were designed by the author with the assistance of Mr. Hugh Boyd and the entire apparatus was constructed in the shops of the steel company.

89 The general arrangement of the governor is shown in Fig. 22 and a chart from the Uehling revolution recorder in Fig. 23. The speed depressions recorded in the latter indicate periods of casting and checks at the furnace.

90 Positive lubrication of the motor cylinders is accomplished by force-feed pumps of the screw-press plunger type. These pumps are driven by lever and ratchet, operated by cams located on the engine cam shaft. The oil pump cams are located in such manner that the oil injection occurs during each compression stroke of the motor piston. There are three oil inlets for each end of the motor cylinder, one at the top and one at each side near the bottom. An individual screw plunger serves each oil inlet which is provided with a check valve.

KOERTING ENGINES

Item	Electric Power	Blowing Engine
Rated h.p.	1000	2000
Speed, r.p.m.	100	35 to 65
Diameter, motor cylinder	$23\frac{3}{4}$	$38\frac{1}{2}$
Stroke, motor cylinder	$43\frac{3}{8}$	60
Diameter, gas pump	$28\frac{3}{4}$	$45\frac{1}{4}$
Diameter, air pump	$25\frac{3}{4}$	$38\frac{1}{4}$
Stroke of pumps	$33\frac{1}{2}$	$49\frac{1}{4}$
Main journals	Four $12\frac{5}{8} \times 23\frac{5}{8}$	Two 18×33 One 22×40 One 22×35
Maximum shaft diameter	$18\frac{1}{2}$	26
Length of shaft	26 ft. 6 in.	34 ft. $7\frac{1}{2}$ in.
Crank pins	Two $12\frac{5}{8} \times 13\frac{3}{4}$	One 24×16 One $18 \times 19\frac{1}{4}$
Crosshead pins	Four $8\frac{1}{4} \times 7\frac{7}{8}$	Four $12\frac{3}{4} \times 11\frac{1}{2}$
Piston rod	$6\frac{5}{16}$	10
Crosshead shoe	$19\frac{3}{4} \times 36\frac{1}{4}$	$27\frac{1}{2} \times 52$
Connecting rod	9 ft. $\frac{1}{4}$ in.	12 ft. 6 in.
Diameter, connecting rod		
Large end	$8\frac{11}{16}$	$12\frac{1}{2}$
Small end	$7\frac{1}{8}$	10
Pump piston rod, diameter	4	$5\frac{1}{2}$
Pump crank pin	$4\frac{5}{16} \times 5\frac{1}{2}$	$6\frac{1}{4} \times 8$
Cam shaft, diameter	$3\frac{1}{8}$	$4\frac{3}{4}$
Motor inlet valve, diameter	$12\frac{5}{8}$	$18\frac{3}{4}$
Gas pump inlet valve, diameter	13	18
Air pump inlet valve, diameter	12	18
Exhaust pipe, diameter	$15\frac{3}{4}$	22
Flywheel, diameter	17 ft. 6 in.	20 ft.
Flywheel weight	45,000	65,000
Blowing cylinder, diameter	—	76
Blowing-engine, stroke	—	60

GENERAL NOTES RELATING TO OPERATION

91 Both gas-cleaning apparatus and the gas engines were installed at an early stage in the history of the art and are necessarily imperfect when compared with modern examples to which have been applied those essential refinements that can be gained only through experience. The average dust content of gas as delivered to the second-washed main amounts to about 50 to 80 mg. per cu.m., equivalent to from 0.022 to 0.035 grains per cu. ft., which would rightly be

considered bad practice in modern gas-cleaning plants. It therefore is fortunate that the type of engine selected is able to operate perfectly well when supplied with this imperfectly cleaned gas, without any distress whatever.

92 Nevertheless, operation of the character named cannot be claimed for the first three years. The author believes, however that esssentially all of the trouble can be traced to several major causes tending to produce premature combustion and a number of minor details not well appreciated at that time.

93 The conditions tending to produce premature combustion and attendant failure of parts subject to the resulting high pressures and temperatures were: imperfect piston packing which was neither properly dowelled nor provided with keepers; unsuitable oil used in the motor cylinders; and high hydrogen content in the gas. Minor causes of premature combustion were: projecting portions of parts exposed to the fire; and accumulations of flue dirt which, in combination with the oil, baked on the surfaces of the parts; the projecting portions remaining incandescent and initiating premature combustion. Minor troubles were also due to various causes, such as wet gas which fouled the igniter points with its accompanying flue dirt; dirty gas which clogged the valves of the controlling devices, making the speed control more difficult; imperfect rod packing, etc., which produced bad atmospheric conditions in the building; inadequacy of certain parts of the 1000-h.p. engines subject to high inertia stresses at 100 r.p.m., etc.

94 Rectangular dowells are now applied to the piston grooves in such secure manner that the openings through the snap rings are confined to a location near the bottom of the cylinder, thus preventing leakage through the openings. The cylinder oil now used does not leave a carbonaceous residue of any considerable magnitude. The pressure of water supply to tuyeres, coolers, and bosh plates is maintained slightly lower than the internal pressure of the furnace; hence cool water cannot enter the furnace to produce excessive hydrogen, following puncture of these parts.

GAS-CLEANING AND SUPPLY SYSTEM

95 As previously noted, there are three gas-cleaning plants, one for each pair of furnaces; and the three delivery mains therefrom are interconnected by means of pressure-equalizing pipes, two in number. These mains for hot gas, cooled gas, and washed gas are locally inter-

connected in parallel relation at each pair of furnaces. It is therefore possible to control the amount of gas taken from each furnace and the gases from the two furnaces are thoroughly mixed by discharging into a common washed-gas delivery main. In order to promote in the best manner uniformity in the constitution of the gas, the delivery from the several washeries should then discharge into a common distributing main or holder. Referring to Fig. 1, however, it will be noted that the locations of the three delivery mains, and the relative locations of the two equalizing pipes are such that it is impossible for such mixing to occur even locally or approximately. A partial solution constituting a great improvement would consist in relocating the 30-in. delivery pipe from washers Nos. 1 and 2 along the west wall of blowing-engine house No. 2, to form a junction at the southwest corner of that building with the 60-in. delivery main from washers Nos. 3 and 4. Also the 36-in. equalizing main should deliver gas into the 60-in. delivery main from washers Nos. 5 and 6, instead of into the north end of the 96-in. header at blowing-engine house No. 3. Power house No. 1 and blowing-engine house No. 2 would then receive the average of gas from four furnaces, whereas at present blowing-engine house No. 2 receives gas only from furnaces 3 and 4, and at power house No. 1, the four north engines may receive gas from furnaces 1 and 2, and the four south engines from furnaces 3 and 4. Under these conditions of piping, the gas supply at any point is but an average of that from two furnaces. and at times the irregularity is considerable, the thermal value occasionally varying between limits of 105 and 80 B.t.u. per cu. ft.. within a period of a few seconds.

96 Owing to the fact that hot gas mains of the three pairs of furnaces are not interconnected, the danger of explosion due to the entrance of air is enhanced to a certain degree, especially when but one furnace of any pair is in operation. This danger is minimized to some extent by means of the equalizing connections between the several washed-gas delivery mains, and the remaining conditions are provided for through the skill and watchfulness of the operators, who are greatly assisted in their work by a system of local telephones, and by indicating and recording vacuum and pressure gages connected at the proper points. Such conditions, however, occur only during checks and casts at the furnace, or in case of failure of the cooling water supply. Such periods are easily taken care of by the operators who thoroughly appreciate the situation. The principal precaution consists in sealing off the connection between towers and dust catcher, before the wind

is taken off the furnace, one furnace of the pair being assumed already out of service. The fans are also shut down or bypassed, and the fan connections sealed off when necessary. there being a diaphragm seal at the suction connection of each fan washer. The most probable point for entrance of air into the system is through the furnace top and connections.

97 Pressure gages are provided at each washer as follows: There is a recording pressure gage for the second-washed main, a recording vacuum and pressure gage for the cooled-gas main, and a manometer connected to tower *D*, Fig. 3.

98 Dirt accumulates on the domes, and on the walls near the tops of towers *A* and *B*, especially during the winter months. The falling of these accumulations, if not otherwise known, is announced by the appearance of overflow water at the emergency seal, due to the closure of the normal outlet for dirt and water at the bottom of the tower. The accumulation at the bottom is then broken up by pokers inserted through the gate valves and pipe tees provided at the bottom drain connection of each tower for that purpose. This occurs on an average of twice a month and occasionally twice a day. These accumulations are largely due to the fact that there is not sufficient pressure to furnish water to the upper three rows of nozzles which are consequently inactive: the dome and upper walls are therefore not washed by flowing water, and the dirt accumulates. The accumulation of dirt in the fan washers and their connections is practically negligible. The water separators require cleaning once, occasionally twice a year. The type of separator shown in Fig. 10 collects dirt more rapidly than the other form. Contemplated improvements are under way for obviating these difficulties.

99 Gas leaves the furnace top at a temperature of about 550 deg. fahr. In summer it enters the fans at about 77 deg. and leaves the fans at about 60 deg. fahr. The water used in the tower amounts to about 75 gal. per 1000 cu. ft. of gas. The quantity of waste water used in the fan washers is not accurately known.

100 At each fan there are eight nozzles which discharge water into the fan through the upper periphery, and four nozzles which discharge it into the gas inlet openings of the fan. The quantity of water used in the fans, especially at the gas inlet, greatly affects the power required to drive them, which increases with the amount of water used. Each fan at washers Nos. 1 and 2 requires about 45 h.p., while about 60 h.p. is required by each fan at washers Nos. 3 to 6. The operation of about one-half of the fan washers is required under present load

conditions. Hence allowing for losses in motors, about five per cent of the delivered horsepower at the engines is required for driving the fan washers.

101 The cleaning of the gas at washers Nos. 1 and 2 is less complete than that at washers Nos. 3 to 6. At the two former the dust content in second-washed gas as delivered averages about 0.035 grains per cu. ft.

102 At gas washers Nos. 3 and 4 the dust content in the gas is about as follows:

Gas	Cooled	First-Washed	Second-Washed
Average grains per cu. ft.	0.328	0.061	0.022
Maximum grains per cu. ft.	0.980	0.100	0.100
Minimum grains per cu. ft.	0.0044	0.0044	0.0044

103 The gas supplied through the 30-in. main to power house No. 1, therefore, contains more dirt and moisture than that delivered from washers Nos. 3 to 6, in consequence of which there is more trouble with dirt at the power house than at the blowing-engine houses. Also it may be noted that the long 8-ft. gas headers at the blowing-engine houses are of probable value in separating the moisture from the gas.

LUBRICATION

104 As previously noted, each motor cylinder is supplied with cylinder oil by six pumps of the screw plunger type. The pumps are arranged in two batteries, one for each end of the cylinder, each comprising three plungers driven by a combination cam, lever, ratchet, and worm gearing, common to the three plungers of the battery. During each compression stroke of the motor piston the three oil pump plungers are depressed through a small distance into the oil pump cylinders. In this way three small equal quantities of oil are forced into the end of the motor cylinder during the corresponding compression stroke of the motor piston, one quantity entering at the top and the others on either side near the bottom of the motor cylinder, at points about midway between the cylinder head and the exhaust ports. The oil pump discharge connections are filled with oil in order to exclude any possibility of the presence of air. The resulting lubrication is thorough, effective and satisfactory. The oil used is known under the trade name of Electric Gas Engine Oil. The flash test is about 450 deg. fahr. and the oil fires at about 550 deg. fahr. The author believes that the long piston of the two-stroke cycle engine is especially conducive to satisfactory cylinder lubrication. The cylin-

der oil used by each blowing engine amounts to about 5.25 gal. every 24 hours.

105 Engine oil known under the trade name of Dynamo Oil is supplied at the necessary points by means of an oil purification and distributing system already described. This oil circulates again and again through the bearings, and each day a sufficient quantity of filtered oil is taken from the system and used for lubricating the piston rods and the gas and air pump cylinders. The quantity of engine oil used by each blowing engine, including oil actually consumed by the air and gas pump cylinders and motor piston rods, plus the daily waste due to leakage, evaporation, etc., in the purification plant, amounts to about 3.7 gal. in 24 hours.

106 In addition to the above there is required for the blowing cylinder about 0.6 gal. of air-cylinder oil, and for small pin bearings, etc., about 1.25 lb. of No. 2 cup grease per 24 hours. The delivered horsepower of each blowing engine varies from 1000 to 1200.

107 The small pipes for delivering oil to the motor cylinder are screw-threaded into the walls of the cylinder, and project radially through the water jacket, passing out through stuffing boxes in the jacket wall. The steel pipe formerly used corroded rapidly, allowing jacket water to enter the motor cylinder during operation. The substitution of brass pipe eliminated this trouble.

108 It was found that dirt accumulated in the two nipples where the oil enters the motor cylinders at each end near the bottom of the cylinder, and gradually baked with the oil, plugging the connection. An appendix consisting of a pipe tee and cock was provided, into which the dirt settled to be blown out at leisure.

IGNITION

109 The detailed construction of the igniter plugs is indicated in Fig. 24. The bronze bushing forming the spherical seat for the movable steel electrode is a driving fit in the cast-iron body of the plug. The cylindrical head of the stationary electrode seats on an asbestos gasket or washer carried by the porcelain insulating plug which is formed as a conical frustrum seated in a cavity in the cast-iron plug on a bedding of litharge and glycerine. Litharge also assists in maintaining tightness between the cast-iron plug and the bronze bushing. This construction is very satisfactory in every way.

110 Using magneto or similar low voltage current, there is little burning of the points, and the life of both electrodes is about one

year. The bronze bushing lasts about six months, this material being the most satisfactory thus far used. The upkeep of the magnetos is relatively expensive, and a ten-volt direct-current system is being substituted.

111 Dirty plugs are caused by slipping furnaces and wet gas containing dirt which fouls and bakes at the terminals. The plugs require cleaning on an average of once to twice per month. The spherical seat requires regrinding once in two months, and the plug must be retubed one in six months.

112 Premature combustion is due to high hydrogen content in the gas, sharp edges or corners of metal exposed to the flame, dirt, and improper piston packing. Back-fires are due to prematures during the period of inlet opening, or to leaking inlet valves under usual conditions. The plant under discussion has had but little of

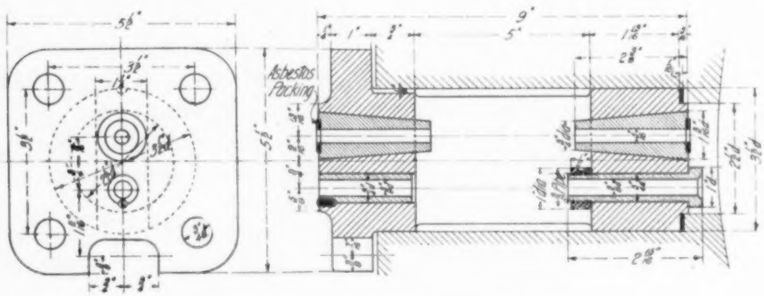


Fig. 24 Details of Igniter Plug

any such trouble. Miss-fires are due to wet gas, faulty plugs or magnetos and weak mixtures.

113 An indicator diagram showing premature ignition is shown in Fig. 25. The maximum pressure indicated in this instance was 385 lb. gage per sq. in.

114 With the type of ignition gear in use there is an interval between the release of the magneto lever and the opening of the igniter terminals. There is also an appreciable time required to complete combustion. This time element being approximately constant, correct ignition requires that the timing of the release shall vary to some extent with the speed of rotation. The ignition gear may then be linked to the speed-adjusting device in such manner as automatically to maintain proper timing of the ignition at all speeds.

GOVERNING

115 When designing the adjustable speed-governing apparatus for the blowing engines it was desired to ascertain these quantitative relations, relative to ignition and speed of rotation, and the results of the investigations that were conducted are given in Appendix No. 1.

116 As far as the author has been able to learn, the method of speed regulation as furnished by the makers, consisted in allowing the gas in the pump discharge pipe to flow through adjustable leakage valves, under control of the governor, back into the suction connection or gas main. For the blowing engines as designed, this bypassing could occur only during the suction stroke of the gas pump; hence

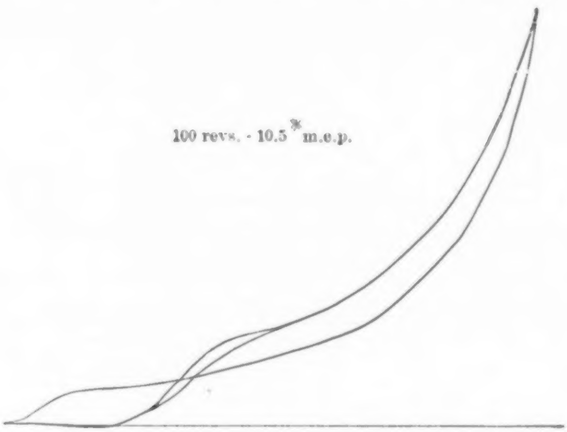


FIG. 25 INDICATOR DIAGRAM OF PREMATURE COMBUSTION

only that portion of gas which was contained in the discharge duct or passage between pump and inlet valve was subject to this control, the result being that after the pressure in the duct discharged through the bypass valve, no further bypassing occurred, the remainder of the gas from the pump passing on into the motor cylinder whether required or not. The blowing engines could not be governed in this manner.

117 As previously noted, at the power house a system of throttle regulation was early applied; and at the blowing engines, governors and valve gears have been applied which allow bypassing to occur during both suction and discharge strokes of the pump. Speed regulation at light load is rather difficult and unsatisfactory on account of miss-fires and other variations in the mean effective pressure, due

to weak and variable mixtures under this condition. Fig. 26 shows the relation between bypass-valve opening and mean effective pressure, for the speed regulating apparatus now in use at the blowing engines. The character of the curve, however, varies considerably with the quality and pressure of the gas.

CYLINDERS, PISTONS, RODS, VALVES, ETC.

118 The average life of a motor cylinder is about four or five years, during which time the wear as measured on a diameter is about three-eighths inches. The cylinder is then bored out and

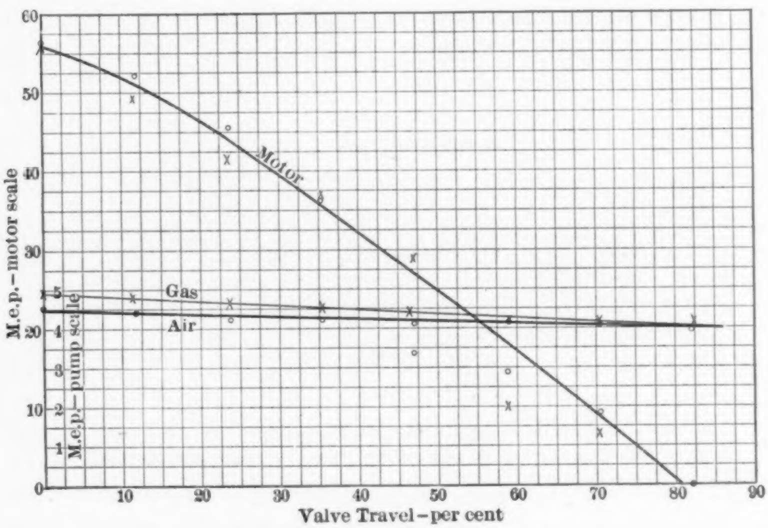


Fig. 26 Calibration of Bypass Valves

bushed. There are practically no cylinder failures from any cause other than wear.

119 Exhaust ports at power house No. 1 become clogged with flue dirt and require cleaning after about three months of operation. Exhaust ports at the blowing-engine houses do not foul at all. The difference is probably due to the cleaner gas at the blowing-engine houses, and possibly in some degree to the precipitation of moisture and dirt in the 96-in. headers.

120 Cylinder relief valves require cleaning about once a month. Jackets of cylinders and heads are cleaned about once a year.

121 Cylinders and pistons are inspected only when conditions indicate. Their wear is measured and recorded at the same time. A test for tightness consists in placing the crank on the dead point and subjecting one end of the cylinder to air or exhaust pressure, the plugs being removed from the opposite head to indicate leakage, if any, through the piston. Details of a $38\frac{1}{2}$-in. cylinder are shown in Fig 17.

122 The $38\frac{1}{2}$-in. pistons have a life of from three to five years. There are but few piston failures due to any cause other than wear. A few have occurred which have been due to the water connections falling down inside the piston and wearing a hole through the bottom. When a piston has worn, say $\frac{5}{16}$ in. at the bottom, it is turned over and used in a standard cylinder. There are at present two standard diameters, $38\frac{1}{2}$ in. for new cylinders and $37\frac{1}{2}$ in. for bushed cylinders.

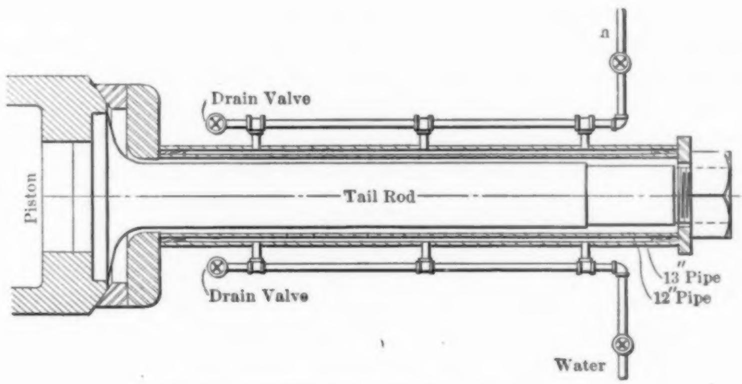


Fig. 27 Device for Stripping Tail Rods

123 The large piston nuts, when dismantling a piston, are heated, removed, cleaned up in the lathe and used again. About half of the small piston nuts have to be split off, the rest being utilized again. There is considerable corrosion around the studs and nuts, and at the joint between rod and piston, thus forming what may be called a rust joint. The tail rods are removed from the piston either by means of the special device shown in Fig. 27 or by means of screw jacks and rams. When using the former, the concentric pipes are first cooled with water and the nut at the end of the tail rod set up; steam is then admitted between the pipes at atmospheric pressure to lengthen the pipes. This cycle is repeated until the rod is free from the piston.

When it becomes necessary to remove the piston rod, the piston is broken away either with dynamite or under the drop hammer.

124 The wear of piston rods occurs principally at the end of the stroke and amounts to about a quarter of an inch on the diameter in three years. It is then turned and will suffice for two or three years more.

125 The average life of the motor cylinder heads is not well established, but it may be set at three years or more. A few of the original heads at the blowing engines are still in service. Failures of these occur principally at the junction of the jacket wall and the main flange on each side of the inlet valve chamber, but this trouble has been substantially eliminated by employing proper fillets. Some heads have developed cracks through the inner wall; two or three have had the inner walls blown entirely away, but this was found due to faulty castings.

126 The inlet valves last about three years before turning and about the same time after they are turned down. They do not require grinding-in except when new. Stems are broken occasionally near the top yoke. Little cleaning of the inlet valve or the ports is necessary.

127 Gas pump cylinders and heads require cleaning every six to eight months on account of dirt getting into the clearance near the bottom. By feeding a little kerosene through the pump valves cleaning is avoided.

128 Cylinder heads are packed principally with $\frac{1}{16}$-in. woven wire insertion asbestos sheet. Piston joints are made up either with $\frac{1}{32}$-in. wetted asbestos paper, or with a paste of litharge and glycerine, or with another form of packing known under the trade name of "900." All give satisfactory results.

129 The life of the $1\frac{7}{16}$-in. snap piston rings is about two years. The openings are securely dowelled in place near the bottom of the cylinder, being thus effectively closed by the piston which is always in contact with the bottom of the cylinder.

130 The piston rods are packed with four cast-iron rings of the Walker type in a casing exterior to the head. Packings are overhauled about every six months to renew broken springs and rings. Casings are trued up at the time of overhauling the piston once in two or three years.

131 The swinging connections for the piston water supply require to be packed about twice a year. The life of the brass goose necks is about two years.

132 Rod connections require keying up on the left side once a year and on the right side once in two months. The main bearings have required no adjustments.

133 The life of the inlet cams is about six years. Wear of the steel gears of the layshaft occurs on four teeth at the end of four or five years; the gears are then shifted on the shaft so that unworn teeth are in action during the inlet valve opening.

134 The inlet valves are operated through heavy push rods driven by cams and rollers. High inertia stresses are thus developed at the higher engine speeds. With present inlet valve springs which operate under a compression of 2500 to 3500 lb. at the blowing engines, the roller leaves contact with the cam at about 65 to 70 r. p.m. Many of the original push rods have been broken by the resulting inertia stresses and new and stronger rods have been made.

135 As previously stated the shaft of the 2000-h.p. engine is of the built-up type and it has been the cause of no trouble whatever. There have been, however, several shaft breakages at the 1000-h.p. engines which have shafts forged in one piece and operate at 100 r.p.m. The author has made no investigation relative to the stresses in these shafts, but believes that their life would have been longer had they been of the built-up type and of present diameters.

136 At the 1000-h.p. engines there has also been trouble with certain brackets and fastenings due to inertia stresses set up by the inlet gear. The governor being driven from the layshaft, considerable wear is imposed on the mechanism due to reversal of the torque at the layshaft as the point of each cam passes under the roller. Some trouble from prematures at the 1000-h.p. engines was experienced, due to the indicator holes through the flange of the cylinder head. Water cooled indicator connections were substituted.

OPERATING COSTS

137 The fuel consumption at the blowing engines amounts to about 18,500 B.t.u. per i.h.p. hour at the blowing cylinder, equivalent to 162,000,000 B.t.u. per h.p. year of 8760 hours. This is equivalent to 5.79 long tons of steam coal which has a heating value of 28,000,000 B.t.u. per ton. Assuming the price of such coal to be $2 per ton, the fuel cost becomes $11.58 per delivered h.p. year of 8760 hours.

138 Other operating costs at blowing-engine house No. 2 for the year 1907 were as follows. A continuous output of 6000 h.p. at the blowing cylinders was assumed, which is as nearly correct as possible, and on this basis the various costs were itemized.

OPERATING COSTS AT BLOWING-ENGINE HOUSE NO. 2 - 1907

Item	Cost per d.h.p. year
Producing labor	$4.504
Labor to repairs and maintenance	0.320
Material to repairs and maintenance	1.152
General	3.962
Total operating cost	$9.94

The total cost of fuel and operation under the conditions assumed is therefore $21.52 per h.p. year of 8760 hours.

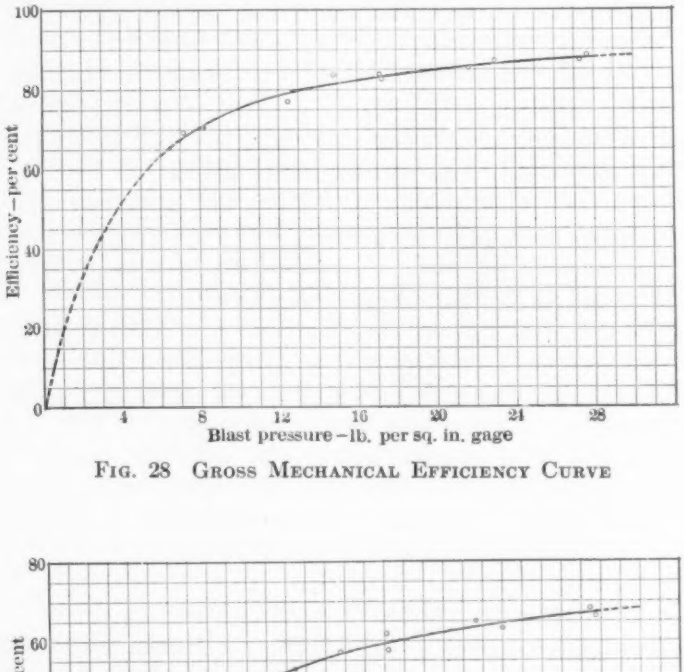


FIG. 28 GROSS MECHANICAL EFFICIENCY CURVE

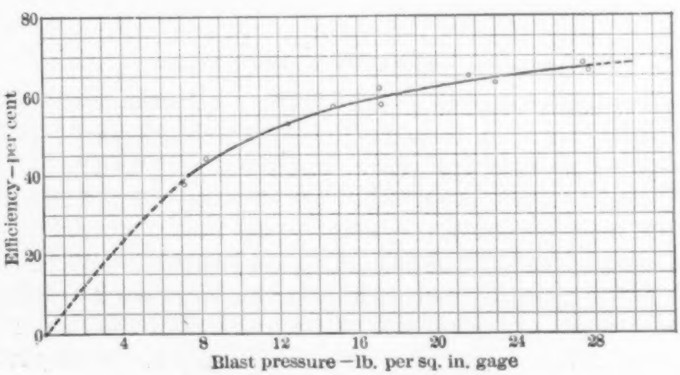


FIG. 29 NET MECHANICAL EFFICIENCY CURVE

OBSERVED QUANTITATIVE RESULTS

139 Some material pertaining to this subject has already been indicated under the heading of General Notes Relating to Operation. A series of efficiency trials, data upon which are tabulated in Appendix No. 3, was run upon one of the blowing engines from which deductions have been made upon the performance of the engine under different conditions of operation.

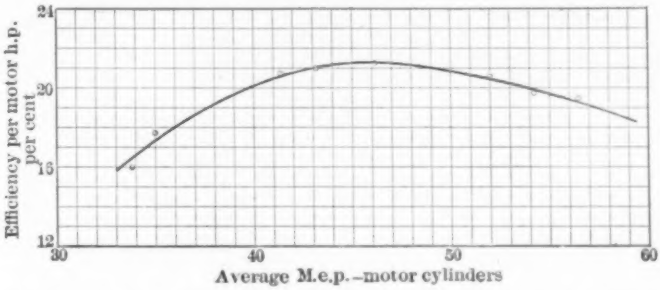


FIG. 30 HEAT TRANSFORMING EFFICIENCY OF MOTOR CYLINDER

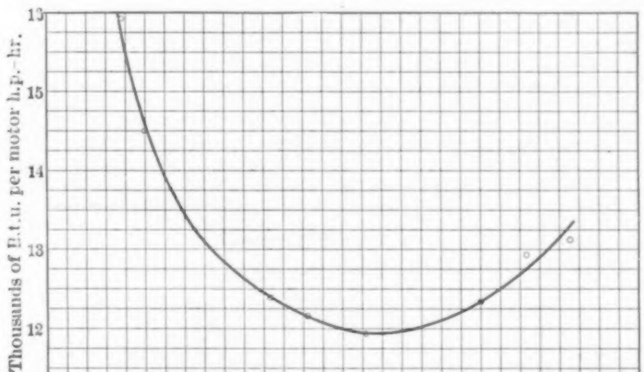


FIG. 31 HEAT CONSUMED PER MOTOR H.P-HOUR

140 The speed regulation during these trials was by throttle and bypass alternately, at least one trial being made under each condition of governing at various blast pressures. In the tabulation, these trials are grouped in pairs, the several blast pressures intended being respectively 5, 10, 15, 20 and 25 lb. per sq. in. nominal gage pressure. It was expected that the bypass method of regulation

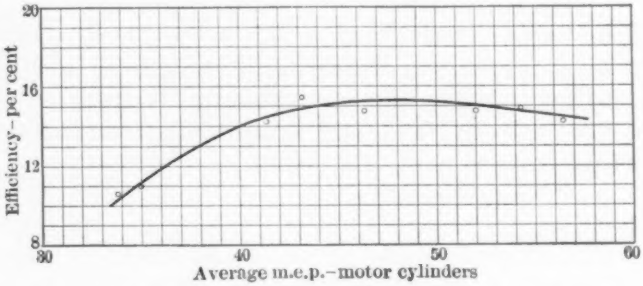


FIG. 32 COMBINED HEAT TRANSFORMING EFFICIENCY OF MOTOR AND PUMP CYLINDERS

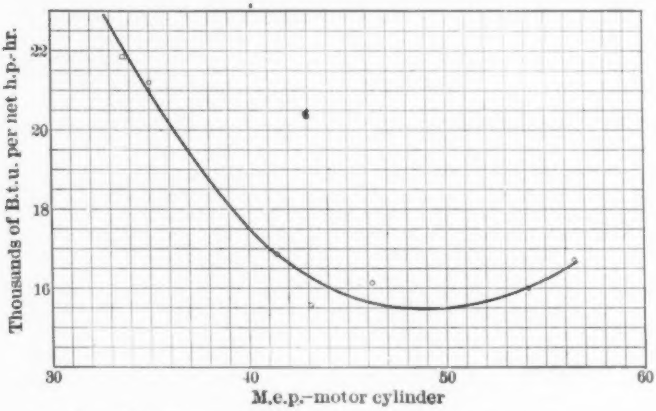


FIG. 33 HEAT CONSUMED PER NET I.H.P-HOUR

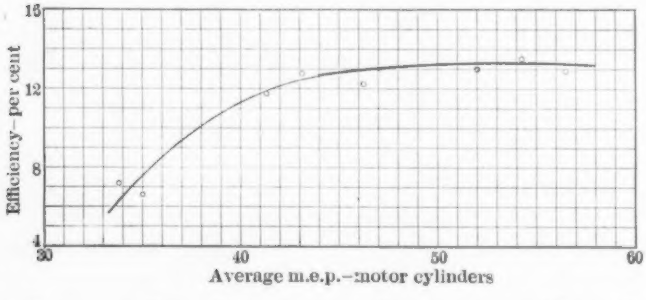


FIG. 34 COMBINED HEAT TRANSFORMING EFFICIENCY OF MOTOR PUMP AND BLOWING CYLINDERS

would show an advantage due to reduced pump work, etc., but such assumption does not seem to be proven, the blast horsepower efficiencies showing substantially the same figure under corresponding load conditions.

141 Fig. 28 represents the gross mechanical efficiency of the mechanism plotted against the blast pressure. It is the ratio of the sum of pump and compressor horsepowers, to the total indicated motor horsepower, and is a measure of the degradation due alone to the mechanical friction of the mechanism. Fig. 29 represents the net mechanical efficiency of the engine, or the ratio of useful work in

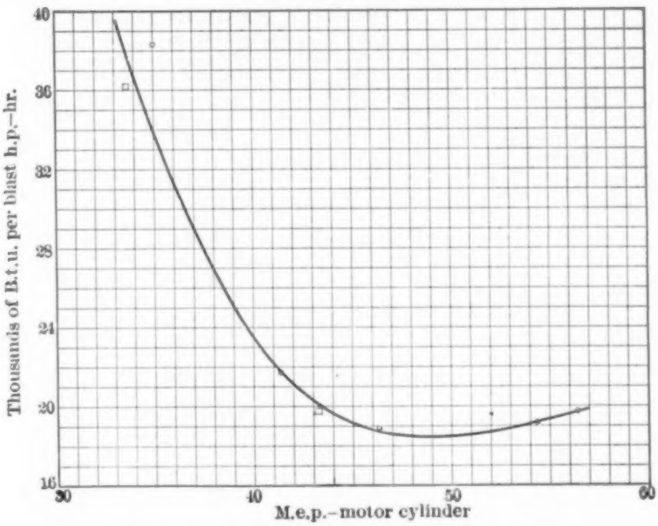


Fig. 35 Heat Consumed per Blast h.p.-hour

the blowing cylinder to total indicated work in the motor cylinders, and is a measure of the loss due to the sum of pump work and mechanical friction. A third figure, which might be termed the "real" mechanical efficiency, would be the ratio of work delivered at the blowing cylinder, to the difference between motor work and pump work; or the ratio of delivered indicated horsepower, to net indicated motor horsepower.

142 The expression net i.h.p. occurring in the tabulated material from the various engine trials is herewith defined as the difference between the total indicated horsepower of the motor cylinders, and the total indicated horsepower of the pumps. Having in mind the

above definition, the curves relating to heat-transforming efficiency, and heat consumption, indicated in Figs. 30 to 35 are self-explanatory.

143 Figs. 36 and 37 are measures of the degradation due to pump work. The curves would have been modified in some degree, had the gas supply pipe and venturi meter been of larger dimensions.

144 Figs. 38 and 39 show the losses due to friction of the mechanism. Figs. 40 and 41 indicate the losses occurring due to incomplete

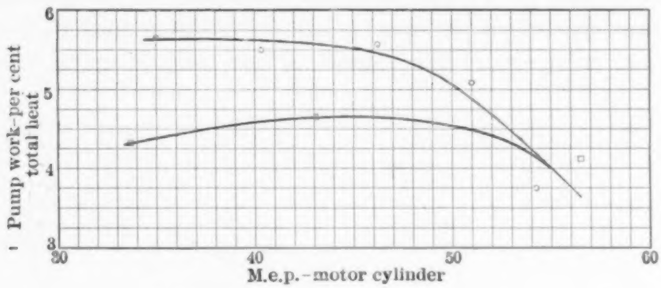


FIG. 36 PUMP WORK—PER CENT

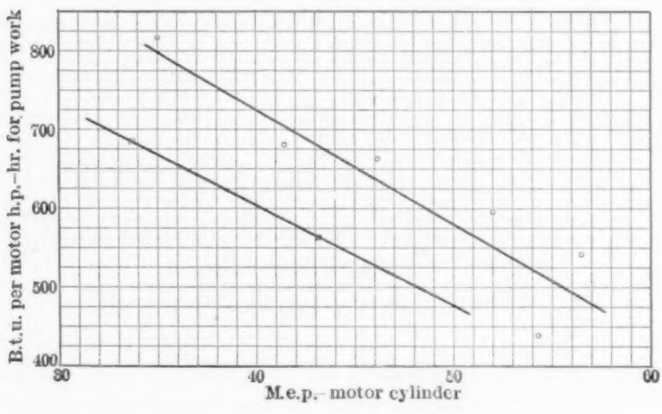


FIG. 37 PUMP WORK—B.T.U. PER MOTOR H.P.-HOUR

combustion in the motor cylinders under the various load conditions. As will be noted the minimum loss due to this cause is about 30 per cent of the total heat supplied to the engine and accounts for the low conversion efficiency of less than 15 per cent shown by these engines.

145 The diagrams of jacket losses shown in Figs. 42 and 43 apparently indicate that losses due to this cause are somewhat erratic

in magnitude. In Fig. 43 an attempt was made to modify these discrepancies by introducing a speed factor, with indifferent success. The jacket loss here shown is believed to be considerably less than is usual with engines of the four-stroke cycle type.

146 Figs. 44 and 45 represent the sensible heat in the exhaust or the balance by difference.

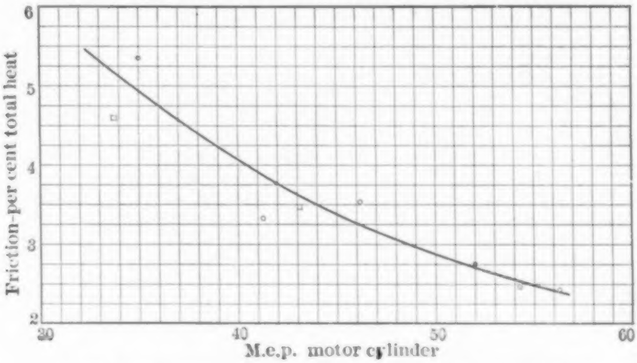


Fig. 38 Friction Loss—per cent of Total Heat

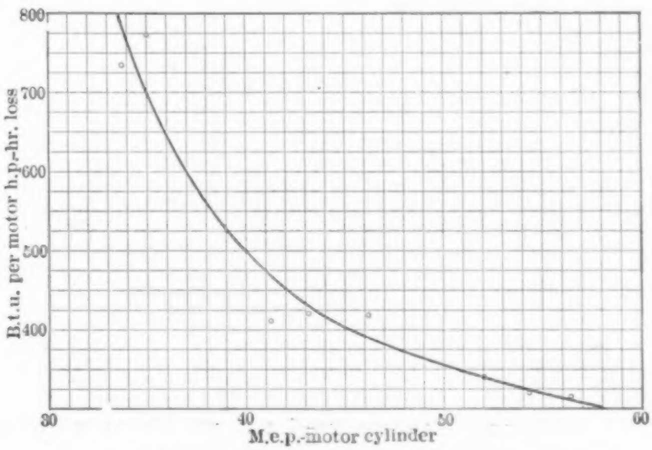


Fig. 39 Friction Loss—B.t.u. per Motor h.p.-hour

147 Fig. 46 is a chart of the various horsepowers plotted against the average blast pressure and Fig. 47 is a diagram of the corresponding percentages based on the motor indicated horsepower and referred to the same abscissae. In Fig. 46 the respective straight line locii of

the motor horsepower and pump horsepower were produced in broken line to intersect the zero axis. The corresponding intercepts show the probable respective values of these quantities at zero blast-pressure. The difference between these two values will then be the probable friction under conditions of zero blast-pressure. From these assumed prob-

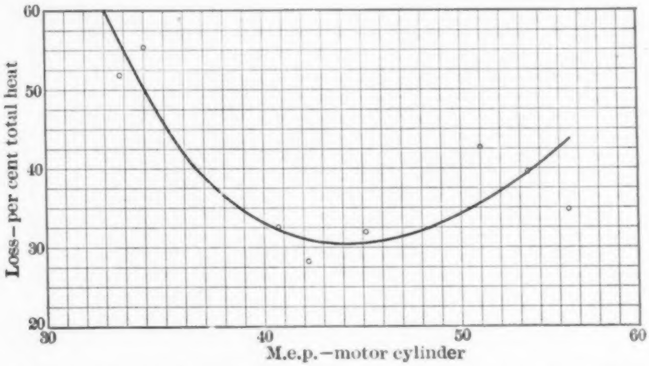


FIG. 40 INCOMPLETE COMBUSTION—PER CENT OF TOTAL HEAT

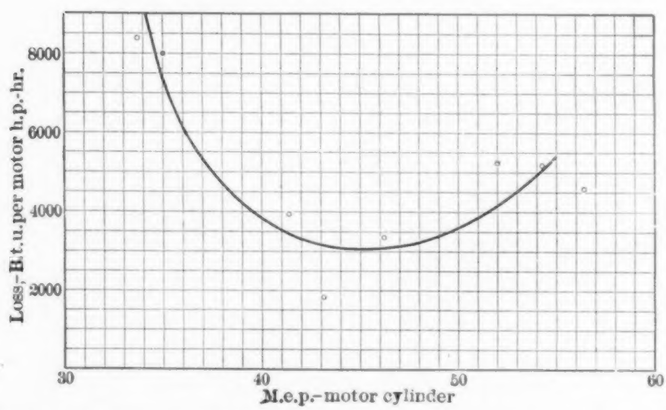


FIG. 41 INCOMPLETE COMBUSTION—B.T.U. PER MOTOR H.P.-HOUR

able values, corresponding figures were calculated to apply to the percentage chart of Fig. 47, and the respective percentage curves were produced, as shown in broken line, to meet these values.

148 It will be observed that the horsepower of friction at constant speed varies in considerable degree, and inversely with the torque

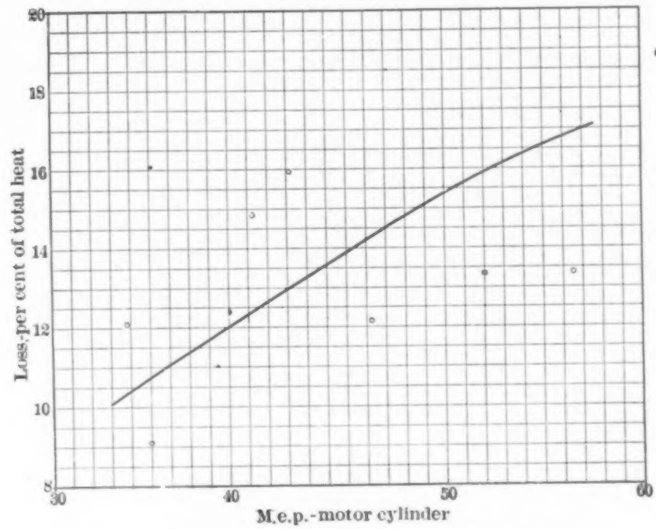


FIG. 42 JACKET LOSS—PER CENT OF TOTAL HEAT

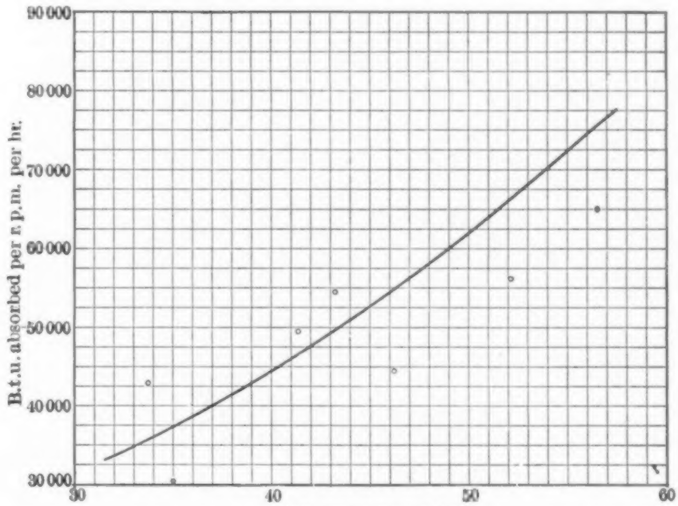


FIG. 43 JACKET LOSS—B.T.U. PER R.P.M. PER HOUR

This may be explained in whole or in part, when it is remembered that the pressure at the bearing is a differential between that due to the inertia of the reciprocating parts and that due to the pressure in the motor cylinder, the inertia pressure being in excess. The bearing

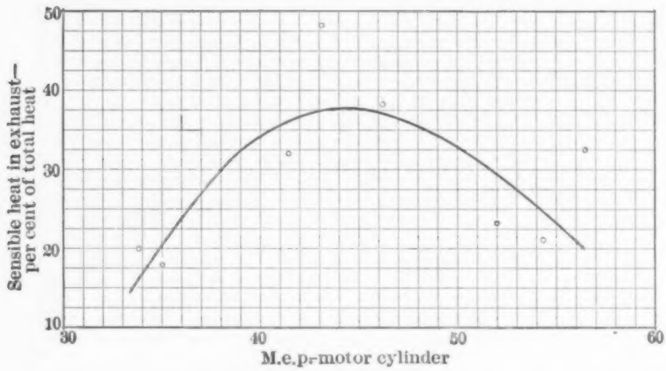


FIG. 44 SENSIBLE HEAT IN EXHAUST—PER CENT OF TOTAL HEAT

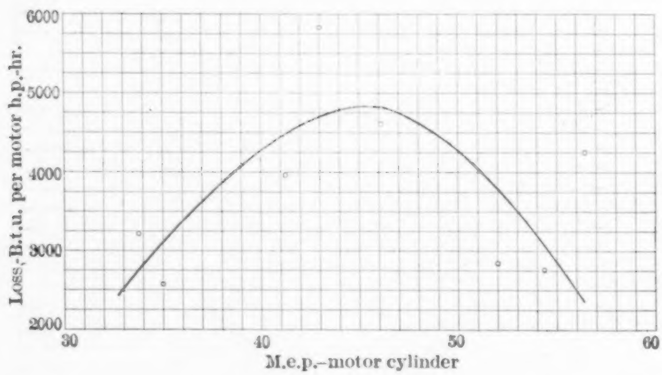


FIG. 45 SENSIBLE HEAT IN EXHAUST—B.T.U. PER MOTOR H. P.-HOUR

pressures at the dead points are therefore reduced by the pressures of compression and explosion.

149 Figs. 48 and 49 are efficiency and heat consumption curves obtained from tests of the 1000-h.p. engines.

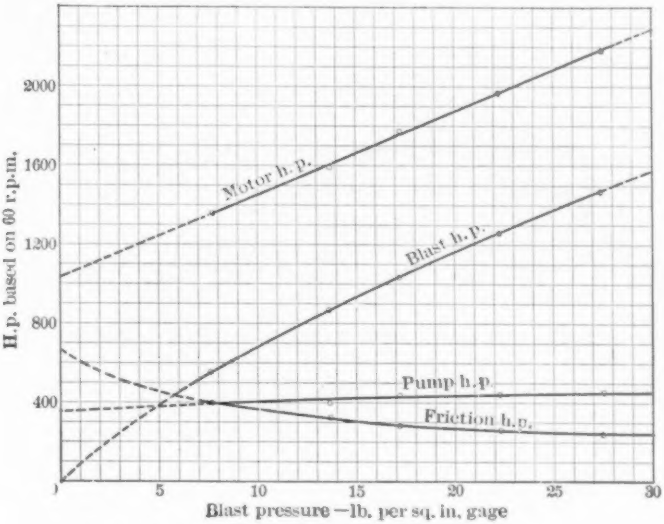


FIG. 46 CURVES OF H.P. AND BLAST PRESSURE

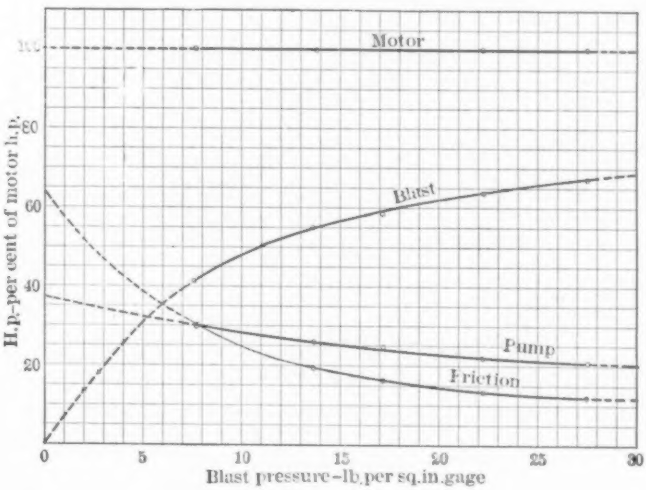


FIG. 47 CURVES OF $\frac{\text{H.P.}}{\text{MOTOR H.P.}}$ AND BLAST PRESSURE

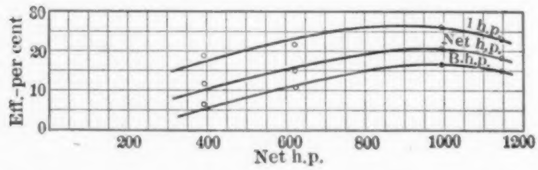


FIG. 48 CURVES OF EFFICIENCY FOR 1000-H.P. ENGINES

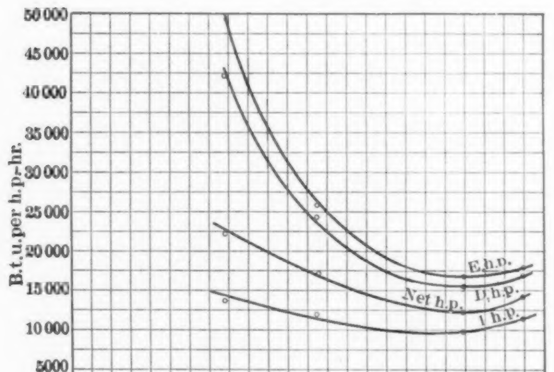


FIG. 49 CURVES OF HEAT CONSUMPTION FOR 1000-H.P. ENGINES

APPENDIX NO. 1

INVESTIGATION TO DETERMINE RELATION BETWEEN POINT OF IGNITION AND SPEED OF ROTATION

150 In this investigation an engine indicator was utilized, the drum motion of the same being derived from the gas pump crosshead. A cord attached to the pencil lever of the indicator was connected first to the magneto lever, and

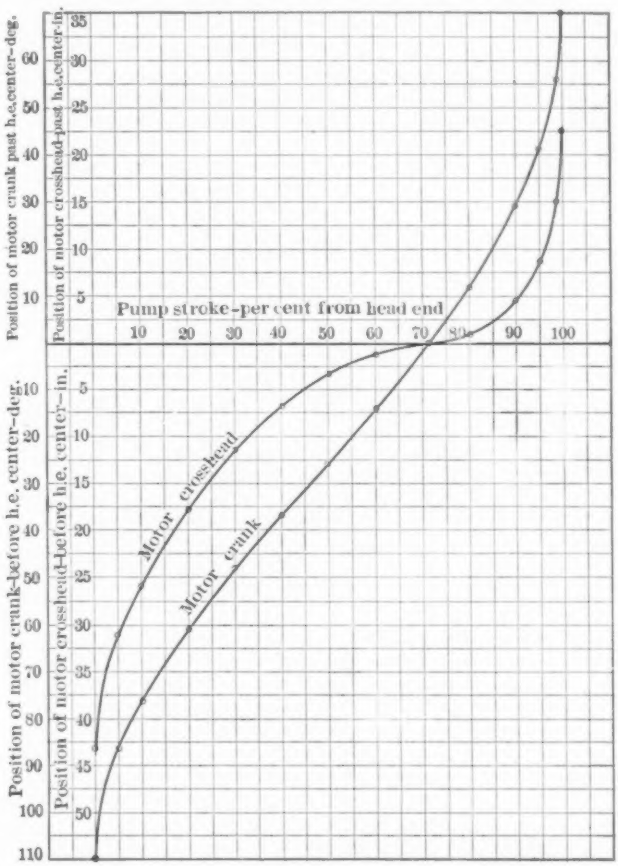


FIG. 50 RELATIVE POSITIONS OF MOTOR CRANK AND CROSSHEAD FOR ANY POSITION OF PUMP CROSSHEAD

second to a crank arm on the igniter stem. In this manner the timing of the magneto release, and of the opening of the igniter terminals, both relative to the motion of the gas pump crosshead, were obtained. This investigation was conducted by E. E. Kiger and the results are shown in the form of curves in Figs. 50 to 54 inclusive.

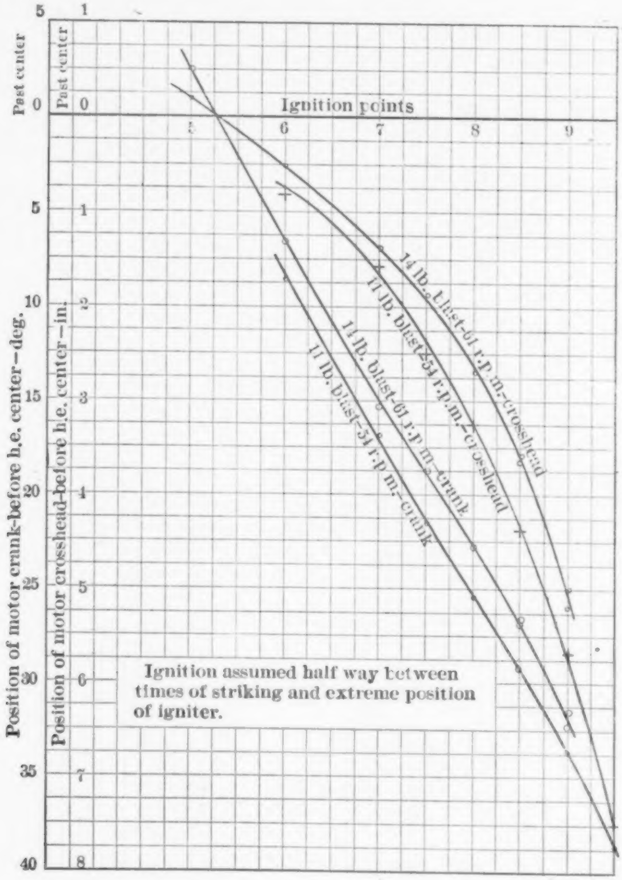


Fig. 51 Positions of Motor Crank and Crosshead for Various Ignition Points when Igniter Opens

151 Following is the explanation of the curves as taken from Mr. Kiger's report.

152 "Curves of Fig. 50 are diagrams of the relative positions of motor crank and motor crosshead to the pump stroke or crosshead, and were drawn by laying out the various positions from the relative crank angles of the engine.

153 "These diagrams were used to locate ignition points relative to motor crank and crosshead after having determined them by experiment relative to the pump crosshead.

154 "Curves on sheet Fig. 51—Diagrams were taken on an indicator pulled from the pump crosshead, the pencil being attached by cord to the igniter. The point taken for ignition is one that is half way between the point of striking the igniter and the extreme position of the igniter. Motor cards were taken together with the ignition cards at different points of ignition from 5 to 9 on the arbitrary index scale of the engine. A series of cards was taken at two speeds, 54 and 61 r.p.m. Enough gas was used at all ignitions to produce good motor

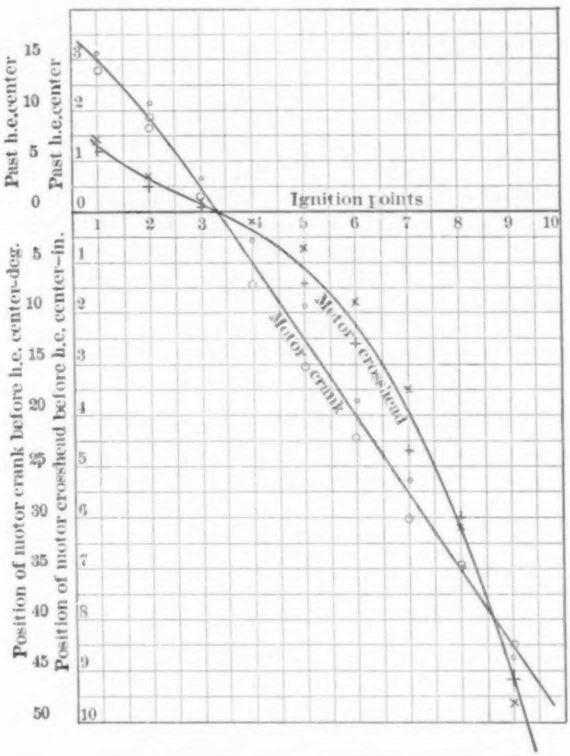


Fig. 52 Positions of Motor Crank and Crosshead at Release of Magneto Lever for Various Ignition Points

cards by regulating the opposite side of the engine. Using curves of Fig. 50, these points were transferred from pump base to motor base as shown on Fig. 51.

155 "Curves of Fig. 52—Location of motor crank and crosshead is shown at release of magneto lever for the various ignition points on the arbitrary scale. Curves were obtained in similar manner to those on Fig. 51, except that the cord was attached to the release lever of the magneto, instead of to the igniter.

156 "Curves on Fig. 53—While Fig. 51 shows positions for two speeds, Fig. 53 shows positions for various speeds, under both normal and checked condi-

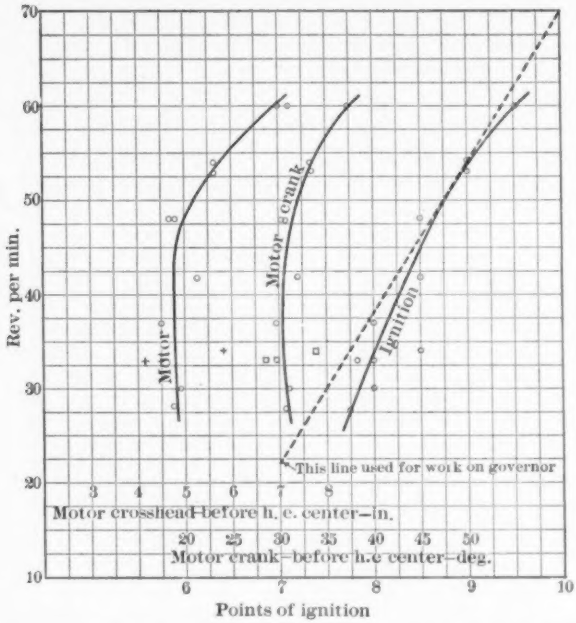


FIG. 53 POSITIONS OF MOTOR CRANK AND CROSSHEAD AND IGNITION POINTS FOR GOOD CARDS AT AVERAGE BLAST AND CHECK CONDITION FOR VARIOUS SPEEDS

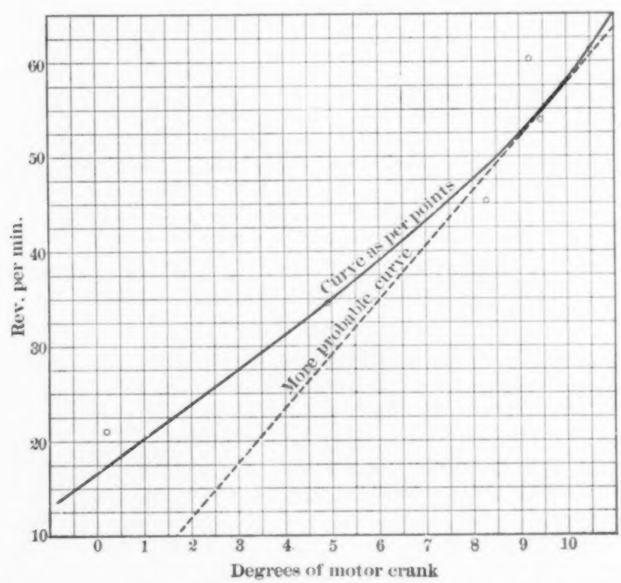


FIG. 54 LAG BETWEEN LEVER RELEASE AND IGNITER OPENING

tions of the furnace. Engine was regulated to give good cards at all speeds. Read by tracing on horizontal from left to right, when intersecting a curve, read down to obtain correct abscissa. A straight line, shown dotted, was used for governor work.

157 "Curves on Fig. 54—Curve as per points was made by combining 52 and 53, giving the lag angle of crank of motor between release of magneto lever and ignition. No points were obtained at low speeds, but at zero speed there would be zero lag angle, therefore the more probable curve is as shown dotted."

158 The motion of the pump was used because of its greater rapidity during the ignition period, thus securing greater accuracy of observation than if the direct motion of the motor crosshead had been utilized. Fig. 53 shows that the actual opening of the igniter circuit occurs under lead angles varying from 30.5 deg. at 30 r.p.m. to 37.5 deg. at 60 r.p.m. in order to produce proper timing of the combustion as determined from simultaneous indicator diagrams of the work in the motor cylinder. The corresponding timing of the release of the magneto lever is seen to vary from about 36 deg. at 30 r.p.m. to 49 deg. at 60 r.p.m. The time at which combustion was complete, as determined from the inspection of simultaneous work diagrams in the motor cylinder, was maintained constant, as nearly as could be estimated, at about 10 deg. past the motor crank center.

APPENDIX NO. 2

DIAGRAM SHOWING LOSSES DUE TO AIR AND GAS PUMPS

159 Fig. 56 shows crank circle diagram of the various events for the motor cylinder, the timing of the various events such as opening and closing the inlet and exhaust valves, etc., being indicated in degrees referred to the motor crank dead points.

160 Figs. 55, 57 and 58 are pressure diagrams taken at the various pump cylinders and connections as noted thereon. Fig. 57 is an average of head and crank diagrams referred to a pump-piston motion base line. Figs. 55 and 58 are similar diagrams referred to the motion of the motor piston. The method of governing at the time these diagrams were taken was throttling. From the diagrams the pressure losses through the various parts of the apparatus supplying air and gas may be deduced. This pump work, amounting to 20 per cent or more of the indicated horsepower, is one of the limiting factors preventing the attainment of the best economy from the engines as constructed.

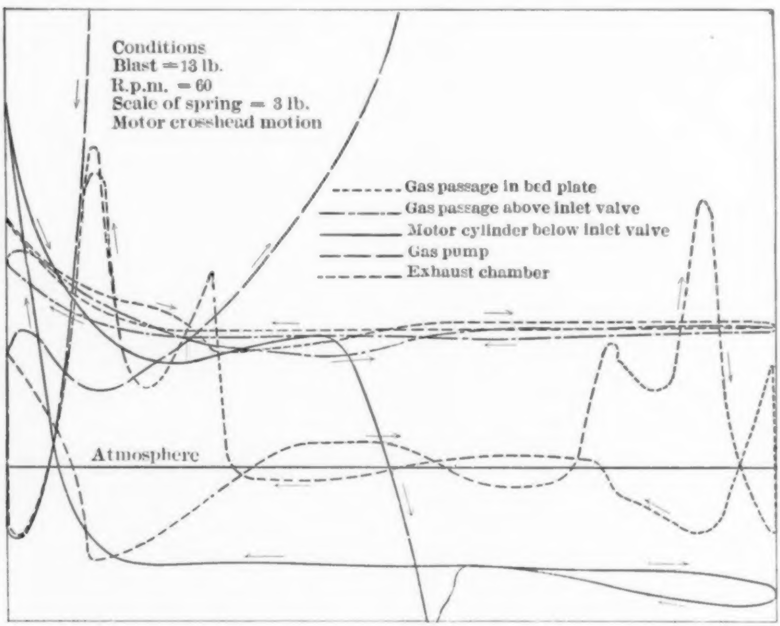


FIG. 55 AVERAGE DIAGRAMS FROM GAS PUMP (MOTOR BASE)

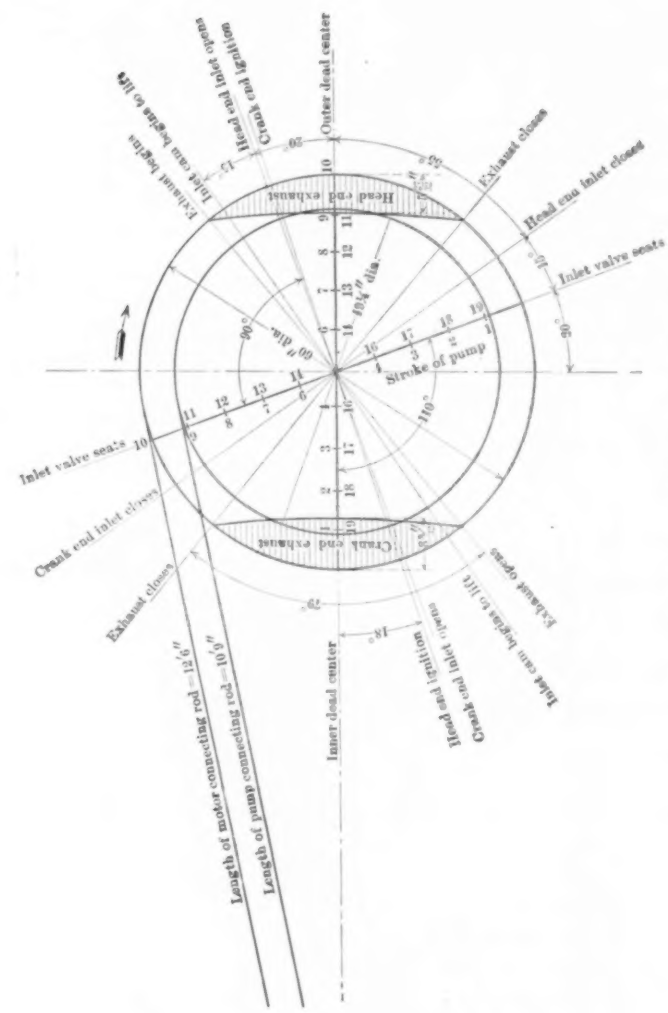


FIG. 56 CRANK CIRCLE DIAGRAM OF MOTOR

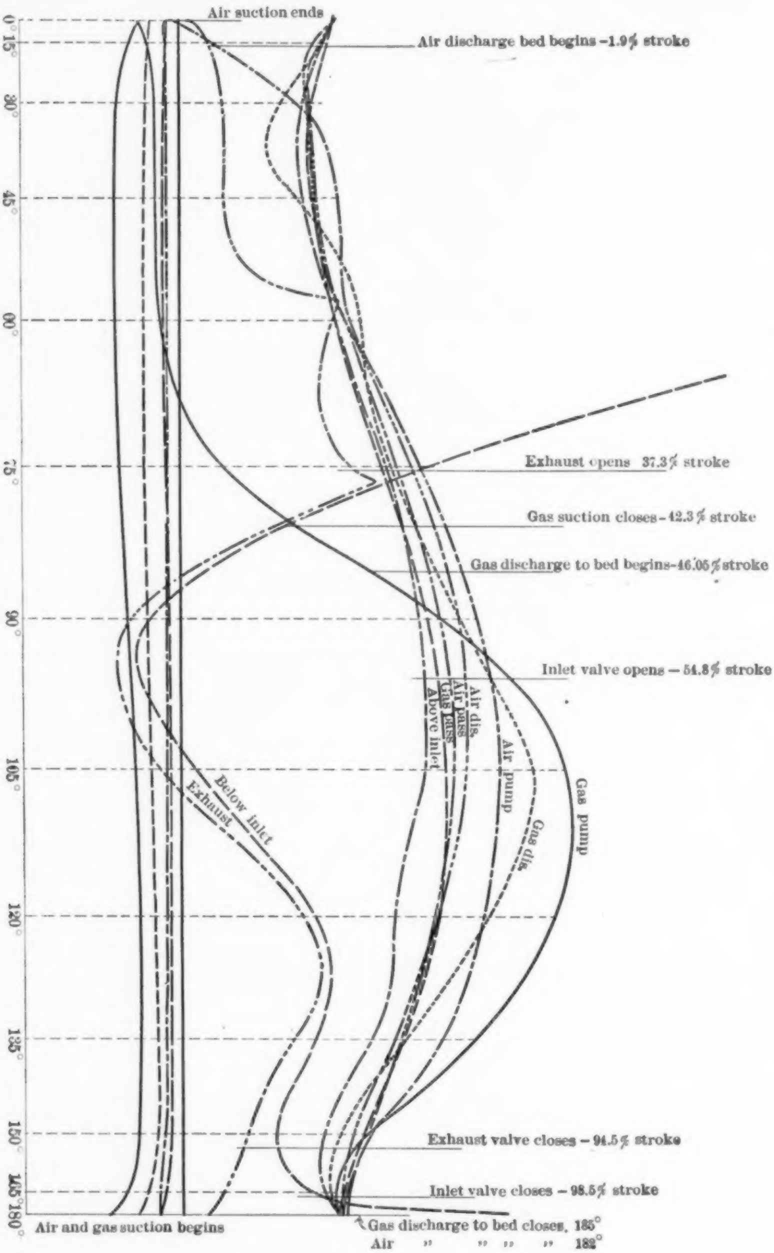


FIG. 57 AVERAGE DIAGRAMS FROM GAS AND AIR PUMPS (PUMP BASE)

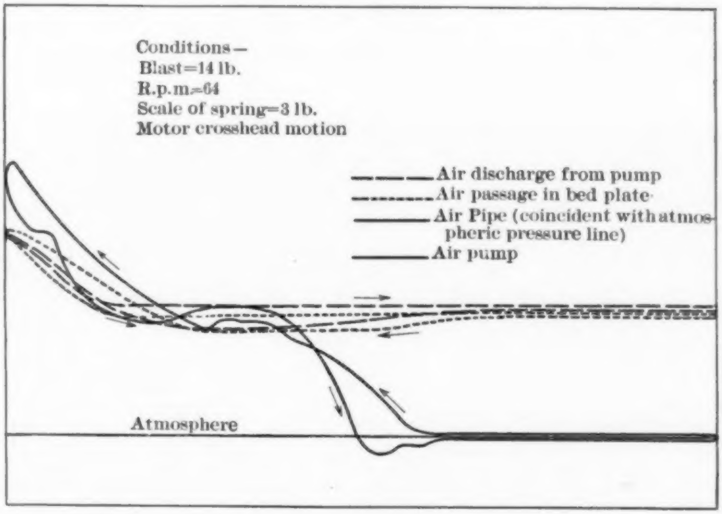


FIG. 58 AVERAGE DIAGRAMS FROM AIR PUMP (MOTOR BASE)

APPENDIX NO. 3

DATA UPON EFFICIENCY TRIALS OF 2000-H.P. BLOWING ENGINE

161 The following matter is principally the tabulation of data and calculated results from a series of efficiency trials at one of the blowing engines.

162 The measurement of the gas was by means of a 16-in. venturi meter in the gas-supply pipe leading to the pumps. The general arrangement of meter, surge tank and piping are shown in Fig. 59. The meter is a little small for the service, in consequence of which the blast pressure could not be carried beyond

FIG. 59 GENERAL ARRANGEMENT OF METER AND PIPING

28 lb. gage. The coefficient of the meter was assumed to be unity, and no corrections were made for dirt or moisture in the gas, same not being observed.

163 The composition of the gas was obtained by means of an Orsat apparatus, which was equipped with a palladium tube for the determination of hydrogen. A continuous sample was taken and analyzed at the end of the trial; another was taken from each of the exhaust pipes and analyzed after the completion of the run. Correction of the carbon-monoxide in the exhaust gases was made as shown in the correction chart for Orsat apparatus, Fig. 60, plotted from the data of Dennis and Edgar. For determining the calorific power of the gas, the high heating value of the gas, as calculated from the analysis, was used.

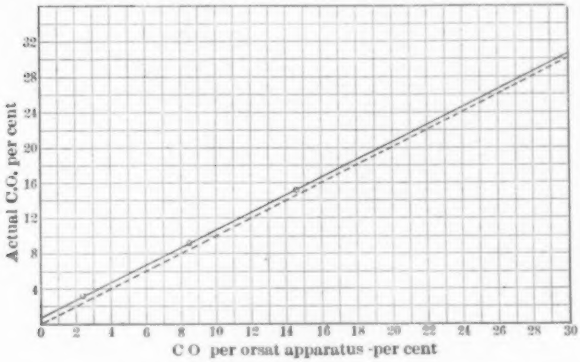


Fig. 60 Correction Chart for Orsat Apparatus

164 The jacket water was determined by means of two orifices in a thin plate, one inserted in each piston water-supply pipe. The calibration curves of these orifices are shown in Figs. 61 and 62.

165 The calibrations of all instruments used for observing pressures and temperatures were known. The diameters of the various cylinders were not calipered, but the error due to this neglect can not be great.

166 Representative indicator diagrams for various of the tests are shown in Figs. 63 to 67. The various efficiencies and heat consumptions are indicated the form of curves. In the plotting of these curves, tests 31 and 36 were disregarded because of discrepancies in the gas analyses.

167 The dilution coefficient of the exhaust gases includes the scavenging air. The method used for obtaining the coefficient is given below.

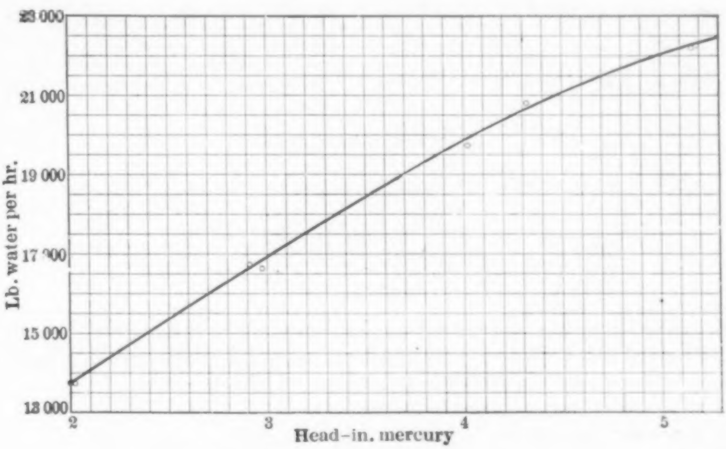


Fig. 61 Orifice Calibration Curves

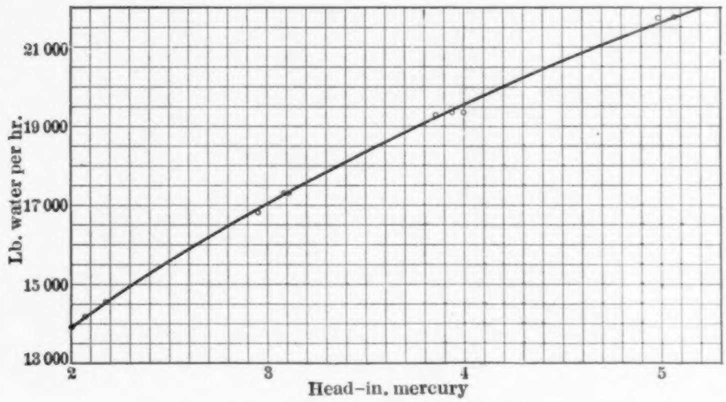


FIG. 62 ORIFICE CALIBRATION CURVES

DILUTION COEFFICIENT OF EXHAUST GASES

Let

N_0 = nitrogen in fuel
N_1 = nitrogen in theoretic air for combustion
N_2 = nitrogen in actual air supplied
N_3 = nitrogen in excess air supplied
N = nitrogen in products of combustion
X = dilution coefficient

$$X = \frac{N_2}{N_1} = \frac{N_2}{N_2 - N_3} = \frac{N_1 + N_3}{N_1} \qquad [1]$$

168 Equation [1] is true for volume or weight analysis, and if little or no nitrogen exists in the fuel, then $N_1 = N$, and, as is usual,

$$X = \frac{N}{N - N_3} \qquad [2]$$

$$= \frac{N}{N - \frac{79}{21}(O - CO)} \text{ for volume analysis}$$

$$= \frac{N}{N - \frac{7677}{2323}\left(O - \frac{16}{28}CO\right)} \text{ for weight analysis}$$

169 In the present instance, where the fuel contained appreciable nitrogen, the following methods and notation were used, the volume analysis of the exhaust gases being reduced to equivalent weight analysis:

A = theoretic air required in lb. per min.
O = weight fraction of oxygen in exhaust gases
CO = weight fraction of CO in exhaust gases

N = weight fraction of nitrogen in exhaust gases
N_o = nitrogen in fuel in lb. per min.
Y = air supplied in lb. per min.
Z = exhaust gases in lb. per min.

$$0.7677\ Y + N_o = NZ = \text{total nitrogen} \qquad [3]$$

$$Y - A = \frac{Z}{0.2323}\left(O - \frac{16}{28}CO\right) = \text{excess air} \qquad [4]$$

$$Z = \frac{N_o + 0.7677\ A}{N - 3.305\left(O - \frac{16}{28}CO\right)}$$

$$Y = \frac{NZ - N_o}{0.7677}$$

$$X = \frac{Y}{A}$$

TEST OF NO. 2 GAS ENGINE AT 7.65-LB. BLAST PRESSURE

DATA RELATING TO TESTS

1 Number of test	27	37
2 Date of test, 1909	April 9	April 15
3 Duration of test, min	60	60
4 Method of regulation	Throttle	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter	16 in., Area 1.396 sq. ft.	
Throat diameter	$6\frac{1}{4}$ in., Area 0.213 sq. ft.	
7 Number of venturi observations	13	13
8 R.p.m. of engine	57.92	57.60
9 Gas pressure, in. water	7.37	12.61
10 P_1-P_2, in. water	16.38	22.23
11 Gas temperature, deg. fahr	36.6	47.5
12 Barometer, in. mercury	29.18	29.63
13 Absolute pipe pressure, lb. per sq. in	14.58749	14.99743
14 Absolute throat pressure, lb. per sq. in	13.99642	14.19526
15 Ratio $\frac{P_2}{P_1}$	0.959481	0.9465
16 $Mf\left(\frac{P_2}{P_1}\right)$	0.3380	0.3863

JACKET WATER

Right Side

17 Water used per hr., lb	8100	11,100
18 Temperature inlet, deg. fahr	39	39.5
19 Temperature discharge, deg. fahr	118	150

Left Side

20 Water used per hr., lb	8650	10,700
21 Temperature inlet, deg. fahr	39	39.5
22 Temperature discharge, deg. fahr	168.1	154.4

Fuel Gas Analysis by Volume

23 CO_2, per cent	8.8	12.8
24 O, per cent	0.3	0.1
25 CO, per cent	28.1	26.2
26 H, per cent	1.0	0.7
27 N (by difference), per cent	61.8	60.2
28 Weight per cu. ft., standard conditions, lb.	0.0814588	0.0834342
29 Weight per cu. ft., test conditions, lb.	0.08016984	0.0826120
30 Heating value per cu. ft., standard conditions, B.t.u.	99.291	91.771
31 Heating value per. cu. ft., test conditions, B.t.u	97.7199	90.8666

Exhaust Gas Analysis by Volume

Right Side		
32 CO, per cent	6.5	9.0
33 O, per cent	13.6	11.8
34 CO, per cent	4.0	4.3
35 N (by difference), per cent	75.9	74.9
Left Side		
36 CO, per cent	5.8	8.6
37 O, per cent	13.4	11.8
38 CO, per cent	4.1	4.4
39 N (by difference), per cent	76.7	75.2

Cylinder Pressures and Horsepowers

Number of test	27	37
Date of test, 1909	April 9	April 15

Mean Effective Pressures

Motor		
Right head	21.46	37.40
Crank	28.73	33.26
Left head	47.21	38.03
Crank	42.60	26.40
Air pump		
Right head	4.37	4.13
Crank	4.71	3.73
Left head	5.30	4.48
Crank	4.66	4.06
Gas pump		
Right head	5.88	4.53
Crank	5.74	4.52
Left head	6.19	5.01
Crank	5.95	4.55
Air tub		
Head	6.17	7.08
Crank	6.51	7.29

Horsepowers

Motor		
Right head	204.47	354.37
Crank	273.73	315.15
Left head	449.81	360.34
Crank	405.89	250.15

Air pump		
Right head	35.56	33.42
Crank	38.19	30.08
Left head	43.13	36.26
Crank	37.79	32.74
Gas pump		
Right head	67.43	51.66
Crank	75.69	51.45
Left head	70.99	57.14
Crank	68.10	51.79
Air tub		
Head	245.62	280.29
Crank	256.29	285.41

RESULTS OF TESTS

1 Number of test	27	37
2 Date of test, 1909	April 9	April 15
3 Method of regulation	Throttle	Bypass
4 Blast pressure, lb	7.1	8.2
5 R.p.m. of engine	57.92	57.60
6 Gas per hr., standard conditions, cu. ft	193,846	222.635
7 Gas per hr., test conditions, cu. ft	196,963	224,851
8 B.t.u. per cu. ft., standard conditions	99.291	91.771
9 B.t.u. per cu. ft., test conditions	97.7199	90.8666
10 Total B.t.u. in gas per hr	19,247,230	20,431,500
11 I.h.p. of motor cylinders	1,333.90	1,280.01
12 I.h.p. of air pumps	154.67	132.50
13 I.h.p. of gas pumps	272.21	212.04
14 I.h.p. of blowing cylinder	501.91	565.70
15 I.h.p. net	907.02	935.47
16 I.h.p. friction	405.11	369.76
17 Gross mechanical efficiency of engine, per cent	69.63	71.28
18 Net efficiency of engine, per cent	37.63	44.19
19 Cu. ft. of gas per i.h.p-hr., standard conditions	145.32	173.93
20 Cu ft. gas per net h.p-hr., standard conditions	213.72	237.99
21 Cu. ft. gas per blast h.p-hr., standard conditions	386.22	393.56
22 B.t.u. per. i.h.p-hr	14,492	15,961
23 B.t.u. per net h.p-hr	21,220	21,841
24 B.t.u. per blast h.p-hr	38,348	36,117
25 Efficiency per i.h.p., per cent	17.64	15.94
26 Efficiency per net h.p., per cent	11.99	11.65
27 Efficiency per blast h.p., per cent	6.64	7.05
28 Dilution coefficient	3.66	2.95
29 Potential heat in exhaust per hr., B.t.u	10,667,950	10,592,600
30 Heat absorbed by jacket water per hr., B.t.u	1,761,670	2,462,630
31 Sensible heat in exhaust, etc. per hr., by difference B.t.u	3,422,750	4,121,030

DISTRIBUTION OF TOTAL HEAT

32 Delivered to the blast, per cent	6.64	7.05
33 Pump work, per cent	5.65	4.29
34 Friction, per cent	5.35	4.60
35 Absorbed by jacket, per cent	9.15	12.05
36 Incomplete combustion, per cent	55.43	51.84
37 Balance by difference, per cent	17.18	20.17

TEST OF NO. 2 GAS ENGINE AT 13.65 LB. BLAST PRESSURE
DATA RELATING TO TESTS

1 Number of test	28	36
2 Date of test, 1909	April 9	April 15
3 Duration of test, min	60	60
4 Method of regulation	Throttle	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter, in	16, area 1.396 sq. ft.	
Throat diameter, in	$6\frac{1}{4}$, area 0.213 sq. ft.	
7 Number of venturi observations	13	13
8 R.p.m. of engine	58	57.92
9 Gas pressure, in. water	7.81	11.01
10 $P_1 - P_2$, in. water	16.43	24.72
11 Gas temperature, deg. fahr	38	42.5
12 Barometer, in. mercury	29.13	29.62
13 Absolute pipe pressure, lb. per sq. in	14.57882	14.93479
14 Absolute throat pressure, lb. per sq. in	13.98594	14.04277
15 Ratio $\frac{P_2}{P_1}$	0.95933	0.9403
16 $Mf\left(\frac{P_2}{P_1}\right)$	0.3385	0.406
Jacket Water		
Right Side		
17 Water used per hr., lb	8000	10,900
18 Temperature inlet, deg. fahr	39	39.5
19 Temperature discharge, deg. fahr	180.8	149.7
Left Side		
20 Water used per hr., lb	12,950	10,750
21 Temperature inlet, deg. fahr	39	39.5
22 Temperature discharge, deg. fahr	172.8	145.1
Fuel Gas Analysis by Volume		
23 CO_2 per cent	8.8	12.6
24 O, per cent	.2	.2
25 CO, per cent	28.4	26.0
26 H, per cent	1.0	1.0
27 N (by difference), per cent	61.6	60.2
28 Weight per cu. ft., standard conditions, lb	0.0814471	0.0831388
29 Weight per cu. ft., test conditions, lb	0.079886	0.0827898
30 Heating value per cu. ft. standard conditions, B.t.u.	100.314	92.13
31 Heating value per cu. ft. test conditions, B.t.u.	98.391	91.7431
Exhaust Gas Analysis by Volume		
Right Side		
32 CO_2 per cent	8.0	9.0
33 O, per cent	12.5	11.0
34 CO per cent	3.0	5.1
35 N (By difference), per cent	76.5	74.9
Left Side		
36 CO_2, per cent	8.0	9.2
37 O, per cent	12.3	11.2
38 CO, per cent	2.8	4.8
39 N (by difference) per cent	76.9	74.8

Cylinder Pressures and Horsepowers

Number of test	28	36
Date of test, 1909	April 9	April 15

Mean Effective Pressures

Motor		
Right head	31.62	40.02
Crank	42.28	37.99
Left head	46.68	44.87
Crank	44.50	33.69
Air pump		
Right head	4.45	4.06
Crank	4.51	3.86
Left head	5.46	4.57
Crank	4.85	4.20
Gas pump		
Right head	5.42	4.62
Crank	5.47	4.60
Left head	6.15	5.26
Crank	5.92	4.72
Air tub		
Head	11.18	9.84
Crank	11.50	10.22

Horsepowers

Motor		
Right head	301.60	381.30
Crank	403.39	361.96
Left head	445.37	427.51
Crank	424.57	320.99
Air pump		
Right head	36.26	33.04
Crank	36.62	31.30
Left head	44.49	37.19
Crank	39.38	34.06
Gas pump		
Right head	62.24	52.98
Crank	62.69	52.65
Left head	70.63	60.32
Crank	67.85	54.02
Air tub		
Head	445.67	391.71
Crank	453.36	402.34

RESULTS OF TESTS

1	Number of test	28	36
2	Date of test, 1909	April 9	April 15
3	Method of regulation	Throttle	Bypass
4	Blast pressure, lb	14.8	12.5
5	R. p. m. of engine	58	57.92
6	Gas per hr., standard conditions, cu. ft.	193,760	234,581
7	Gas per hr., test conditions	197,546	235,570
8	B.t.u. per cu. ft., standard conditions	100.314	92.13
9	B.t.u. per cu. ft., test conditions	98.391	91.7431
10	Total B.t.u. in gas per hr	19,436,800	21,611,970
11	I.h.p. of motor cylinders	1575.02	1491.76
12	I.h.p. of air pumps	156.75	135.59
13	I.h.p. of gas pumps	263.41	219.97

14 I.h.p. of blowing cylinder	899.03	794.05
15 I.h.p. net	1154.86	1136.20
16 I.h.p. friction	255.83	342.15
17 Gross mechanical efficiency of engine, per cent	83.76	77.07
18 Net mechanical efficiency of engine, per cent	57.08	53.23
19 Cu. ft. of gas per i.h.p. hr., standard conditions	123.02	157.25
20 Cu. ft. gas per net h.p., hr., standard conditions	167.78	206.46
21 Cu. ft. gas per blast h.p., hr., standard conditions	215.52	295.42
22 B.t.u. per i.h.p-hr	12,341	14,488
23 B.t.u. per net h.p-hr	16,830	19,021
24 B.t.u. per blast h.p-hr	21,620	27,217
25 Efficiency per i.h.p., per cent	20.62	17.57
26 Efficiency per net h.p	15.12	13.38
27 Efficiency per blast h.p., per cent	11.77	9.35
28 Dilution coefficient	3.45	4.081
29 Potential heat in exhaust per hr., B.t.u	6,313,100	13,505,700
30 Heat absorbed by jacket water per hr. B.t.u	2,878,390	2,342,880
31 Sensible heat in exhaust, etc. per hr. by difference, B.t.u	6,236,880	1,966,690
Distribution of Total Heat		
32 Delivered to the blast, per cent	11.77	9.35
33 Pump work, per cent	5.50	4.19
34 Friction, per cent	3.35	4.03
35 Absorbed by jackets, per cent	14.81	10.84
36 Incomplete combustion, per cent	32.48	62.49
37 Balance by difference, per cent	32.09	9.10

TEST OF NO. 2 GAS ENGINE AT 17.15-LB. BLAST PRESSURE

1 Number of test	29	30
2 Date of test, 1909	April 10	April 10
3 Duration of test, min	60	60
4 Method of regulation	Throttle	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter, in	16, Area 1.396 sq. ft.	
Throat diameter, in	$6\frac{1}{4}$. Area 0.213 sq. ft.	
7 Number of venturi observations	13	13
8 R.p.m. of engine	61.35	59.75
9 Gas pressure, in. water	9.35	14.51
10 P_1-P_2, in. water	27.33	21.78
11 Gas temperature, deg. fahr	39.6	38
12 Barometer, in. mercury	29.53	29.58
13 Absolute pipe pressure, lb. sq. in	14.83071	15.04146
14 Absolute throat pressure	13.84451	14.25553
15 Ratio $\frac{P_2}{P_1}$	0.933503	0.94775
16 $Mf\left(\frac{P_2}{P_1}\right)$	0.427	0.382
Jacket Water		
Right Side		
17 Water used per hr., lb	8975	13,050
18 Temperature inlet, deg. fahr	38	40
19 Temperature discharge, deg. fahr	153.4	173.7
Left Side		
20 Water used per hr	14,800	11,950
21 Temperature inlet, deg. fahr	38	40
22 Temperature discharge, deg. fahr	151	167.70

Fuel Gas Analysis by Volume

23 CO_2, per cent	10.4	10.7
24 O, per cent	0.2	0.2
15 CO, per cent	25.7	26.4
26 H, per cent	1.3	0.5
27 N (by difference), per cent	62.4	62.2
28 Weight per cu. ft., standard conditions, lb	0.0819455	0.0826587
29 Weight per cu. ft., test conditions, lb	0.077834	0.0836471
30 Heating value per cu. ft., standard conditions, B.t.u.	92.149	91.759
31 Heating value per cu. ft., test conditions, B.t.u	87.5255	92.8562

Exhaust Gas Analysis by Volume

Right Side		
32 CO_2 per cent	9.1	11.0
33 O, per cent	11.4	10.5
34 CO, per cent	2.1	0.5
35 N (by difference), per cent	77.4	78.0
Left Side		
36 CO_2 per cent	9.1	9.5
37 O, per cent	11.1	11.1
38 CO, per cent	2.0	1.1
39 N (by difference)	77.8	78.3

Cylinder Pressures and Horsepowers

Number of test	29	30
Date of test, 1909	April 10	April 10

Mean Effective Pressures

Motor		
Right head	39.66	44.06
Crank	45.64	44.84
Left head	48.76	41.95
Crank	50.79	41.49
Air pump		
Right head	5.28	4.41
Crank	5.56	4.25
Left head	6.02	4.73
Crank	5.45	4.42
Gas pump		
Right head	5.96	4.57
Crank	5.89	4.82
Left head	6.31	5.07
Crank	6.20	4.76
Air tub		
Head	12.73	12.74
Crank	12.76	12.66

Horsepowers

Motor		
Right head	400.25	433.06
Crank	460.60	440.73
Left head	492.09	412.32
Crank	512.58	407.80
Air pump		
Right head	45.51	37.02
Crank	47.75	35.55
Left head	51.89	39.71
Crank	46.81	36.97

Gas pump		
Right head	72.40	54 07
Crank	71.40	56.91
Left head	76.65	59.98
Crank	75.16	56.20
Air tub		
Head	536.77	523.18
Crank	532.09	514.15

RESULTS OF TESTS

1 Number of test	29	30
2 Date of test, 1909	April 10	April 10
3 Method of regulation	Throttle	Bypass
4 Blast pressure, lb	17.2	17.1
5 R.p.m. of engine	61.35	59.75
6 Gas per hr., standard conditions, cu. ft	241,853	223,940
7 Gas per hr., test conditions, cu. ft	254,630	221,293
8 B.t.u. per cu. ft., standard conditions	92.149	91.759
9 B.t.u. per cu. ft., test conditions	87.5255	92.8562
10 Total B.t.u. in gas per hr	22,286,500	20,548,400
11 I.h.p. of motor cylinders	1,865.52	1,693.91
12 I. h.p. of air pumps	191.96	149.25
13 I.h.p of gas pumps	295.61	227.16
14 I.h.p. of blowing cylinder	1068.86	1037.33
15 I.h.p. net	1377.95	1317.50
16 I.h.p. friction	309.09	280.17
17 Gross mechanical efficiency of engine, per cent	83.43	84.43
18 Net mechanical efficiency of engine, per cent	57.30	61.24
19 Cu. ft. gas per h.p. hr., standard conditions	129.64	132.20
20 Cu. ft. gas per net h.p. hr., standard conditions	175.52	169.97
21 Cu. ft. gas per blast h.p. hr., standard conditions	226.27	215.88
22 B.t.u. per i.h.p-hr	11,948	12,131
23 B.t.u. per net h.p-hr	16,174	15,597
24 B.t.u. per blast h.p-hr	20,850	19,809
25 Efficiency per i.h.p., per cent	21.30	20.98
26 Efficiency per net h.p., per cent	15.74	16.32
27 Efficiency per blast h.p., per cent	12.21	12.85
28 Dilution coefficients	3.1	3.149
29 Potential heat in exhaust per hr., B.t.u	6,243,500	3,048,400
30 Heat absorbed by jacket water per hr	2,715,250	3,282,940
31 Sensible heat in exhaust, etc., per hr. by difference, B.t.u	8,582,500	9,904,330
Distribution of Total Heat		
32 Delivered to the blast, per cent	12.21	12.85
33 Pump work, per cent	5.56	4.66
34 Friction, per cent	3.53	3.47
35 Absorbed by jacket, per cent	12.18	15.98
36 Incomplete combustion, per cent	28.01	14.84
37 Balance of difference, per cent	38.51	48.20

TEST OF NO. 2 GAS ENGINE AT 22.35-LB. BLAST PRESSURE

1 Number of test	32	31
2 Date of test, 1909	April 12	April 12
3 Duration of test, min	60	60
4 Method of regulation	Throttle	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter, in	16, Area, 1.396 sq.ft.	
Throat diameter, in	6½, Area, 0.213 sq.ft.	

7 Number of venturi observations	13	13
8 R.p.m. of engine	51.65	59.72
9 Gas pressure, in water	11.75	12.75
10 P_1-P_2, in. water	38.33	25.51
11 Gas temperature, deg. fahr	60	61
12 Barometer, in mercury	29.43	29.52
13 Absolute pipe pressure, lb. sq. in	14.86824	14.9485
14 Absolute throat pressure, lb. sq. in	13.48510	14.02797
15 Ratio $\dfrac{P_2}{P_1}$	0.096973	0.93842
16 $Mf\left(\dfrac{P_2}{P_1}\right)$	0.4968	0.412

JACKET WATER

Right side		
17 Water used per hr., lb	12,600	12,200
18 Temperature inlet, deg. fahr	40.5	40.5
19 Temperature discharge, deg. fahr	178.3	154.3
Left side		
20 Water used per hr., lb	13,100	12,650
21 Temperature inlet, deg. fahr	40.5	40.5
22 Temperature discharge, deg. fahr	172.7	167

FUEL GAS ANALYSIS BY VOLUME

23 CO_2 per cent	12.7	11.3
24 O, per cent	0.2	0.1
25 CO, per cent	26.5	24.1
26 H, per cent	0.7	0.7
27 N (by difference), per cent	59.9	63.8
28 Weight per cu. ft., standard conditions, lb	0.0834002	0.0827742
29 Weight per cu. ft. test conditions, lb	0.0799028	0.0795783
30 Heating value per cu.ft. standard conditions, B.t.u	92.794	84.61
31 Heating value per cu. ft. test conditions, B.t.u	88.9072	81.3433

EXHAUST GAS ANALYSIS BY VOLUME

Right Side		
32 CO_2 per cent	11.2	11.7
33 O, per cent	9.8	9.8
34 CO per cent	4.6	2.4*
35 N (by difference), per cent	74.4	76.1
Left Side		
36 CO_2 per cent	11.6	10.2
37 O, per cent	9.6	10.1
38 CO, per cent	4.0	2.6
39 N (By difference)	74.8	77.1

CYLINDER PRESSURES AND HORSEPOWERS

Number of test	32	31
Date of test, 1909	April 12	April 12

MEAN EFFECTIVE PRESSURES

Motor		
Right head	48.89	45.51
Crank	52.16	59.06
Left head	52.70	50.06
Crank	54.31	48.41

*Assumed value.

Air pump		
Right head	5.68	4.39
Crank	5.93	4.20
Left head	6.31	4.90
Crank	5.78	4.52
Gas pump		
Right head	5.82	4.64
Crank	5.80	4.85
Left head	6.21	5.31
Crank	5.99	4.96
Air tub		
Head	15.40	14.78
Crank	16.23	15.47

Horsepowers

Motor		
Right head	495.81	447.09
Crank	528.98	481.96
Left head	534.45	491.79
Crank	550.78	475.58
Air pump		
Right head	49.20	36.84
Crank	51.18	35.12
Left head	54.66	41.11
Crank	49.89	37.79
Gas pump		
Right head	71.04	54.87
Crank	70.66	57.23
Left head	75.80	62.79
Crank	72.97	58.53
Air tub		
Head	652.53	606.65
Crank	680.09	627.95

RESULTS OF TESTS

1 Number of test	32	31
2 Date of test, 1909	April 12	April 12
3 Method of regulation	Throttle	Bypass
4 Blast pressure, lb	23.0	21.7
5 R.p.m. of engine	61.65	59.72
6 Gas per hr., standard conditions, cu. ft	280,485	234,521
7 Gas per hr., test conditions, cu. ft	292,762	243,937
8 B.t.u. per cu. ft., standard conditions	92.794	84.61
9 B.t.u. per cu. ft., test conditions	88.9027	81.3433
10 Total B.t.u. in gas per hr	26,027,300	19,842,850
11 I.h.p. of motor cylinders	2110.02	1896.42
12 I.h.p. of air pumps	204.93	150.86
13 I.h.p. of gas pumps	290.47	233.42
14 I.h.p. of blowing cylinder	1332.62	1234.60
15 I.h.p. net	1461.62	1512.14
16 I.h.p. friction	282.00	277.54
17 Gross mechanical efficiency of engine, per cent	86.64	85.37
18 Net mechanical efficiency of engine, per cent	63.16	65.10
19 Cu. ft. gas per i.h.p. hr., standard conditions	132.93	123.67
20 Cu. ft. gas per net h.p. hr., standard conditions	154.57	155.09
21 Cu. ft. gas per h.p. hr., standard conditions	210.48	189.96
22 B.t.u. per i.h.p-hr	12,335	10,464
23 B.t.u. per net. h.p-hr	14,343	13,122
24 B.t.u. per blast h.p-hr	19,531	16,072

25 Efficiency per i.h.p., per cent	20.63	24.32
26 Efficiency per net h.p., per cent	15.79	19.39
27 Efficiency per blast h.p., per cent	13.03	15.83
28 Dilution coefficient, per cent	2.267	2.686
29 Potential heat in exhaust per hr., B.t.u	11,159,000	6,178,480
30 Heat absorbed by jacket water per hr., B.t.u	3,481,200	2,998,690
31 Sensible heat in exhaust, etc., per hr. by difference, B.t.u.	6,017,500	5,839,760

Distribution of Total Heat

32 Delivered to the blast, per cent	13.03	15.83
33 Pump work, per cent	4.84	4.93
34 Friction, per cent	2.76	3.56
35 Absorbed by jackets, per cent	13.38	15.11
36 Incomplete combustion, per cent	42.87	31.14
37 Balance by difference, per cent	23.12	29.43

TEST OF NO. 2 GAS ENGINE AT 27.5-LB. BLAST PRESSURE

1 Number of test	33	35
2 Date of test, 1909	April 13	April 14
3 Duration of test, min	60	60
4 Method of regulation	Bypass	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter, in	16, Area, 1.396 sq. ft.	
Throat diameter, in	$6\frac{1}{4}$, Area, 0.213 sq. ft.	
7 Number of venturi observations	13	13
8 R.p.m. of engine	54.45	58.62
9 Gas pressure, in. water	11.01	10.94
10 P_1-P_2, in. water	38.88	51.65
11 Gas temperature, deg. fahr	62.6	42
12 Barometer, in. mercury	29.08	29.53
13 Absolute pipe pressure, lb. per sq. in	14.66976	14.88809
14 Absolute throat pressure, lb. per sq. in	13.26678	13.0243
15 Ratio $\frac{P_2}{P_1}$	0.90436	0.8748
16 $Mf\left(\frac{P_2}{P_1}\right)$	0.5025	0.5645

Jacket Water

Right Side

17 Water used per hr., lb	18,650	16,300
18 Temperature inlet, deg. fahr	42.3	40
19 Temperature discharge, deg. fahr	167.1	147.4

Left Side

20 Water used per hr., lb	20,000	17,650
21 Temperature inlet, deg. fahr	42.3	40
22 Temperature discharge, deg. fahr	169	156.4

Fuel Gas Analysis By Volume

23 CO_2 per cent	12.0	13.1
24 O, per cent	0.1	0.2
25 CO, per cent	25.9	24.3
26 H, per cent	0.5	1.4
27 N (by difference), per cent	51.5	61.0
28 Weight per cu. ft., standard conditions, lb	0.0832257	0.083047
29 Weight per cu. ft., test conditions, lb	0.0782805	0.0825485
30 Heating value per cu. ft., standard conditions, B.t.u.	90.054	87.721
31 Heating value per cu. ft., test conditions, B.t.u.	84.7031	87.1661

Exhaust Gas Analysis by Volume

Right Side		
32 CO_2 per cent	12.1	12.1
33 O, per cent	8.5	8.7
34 CO, per cent	4.5	3.5
35 N (by difference), per cent	74.8	75.7
Left Side		
36 CO_2, per cent	12.4	11.6
37 O, per cent	8.2	9.0
38 CO, per cent	4.1	3.4
39 N (by difference), per cent	75.3	76.0

Cylinder Pressures and Horsepowers

Number of test	33	35
Date of test, 1909	April 13	April 14
Effective Pressures		
Motor		
Right head	51.74	51.90
Crank	53.42	55.37
Left head	56.44	59.59
Crank	55.59	59.01
Air pump		
Right head	4.88	5.79
Crank	4.92	5.79
Left head	5.61	6.88
Crank	5.20	6.34
Gas Pump		
Right head	4.64	5.47
Crank	4.85	5.46
Left head	5.34	6.32
Crank	5.12	6.04
Air tub		
Head	17.36	17.60
Crank	18.39	18.53
Horsepowers		
Motor		
Right head	463.44	500.47
Crank	478.48	533.93
Left head	505.53	574.63
Crank	497.92	569.03
Air pump		
Right head	37.33	47.69
Crank	37.51	47.52
Left head	42.92	56.66
Crank	39.64	52.03
Gas pump		
Right head	50.02	63.49
Crank	52.18	63.24
Left head	57.57	73.35
Crank	55.09	70.19
Air tub		
Head	649.67	709.10
Crank	680.61	738.31

RESULTS OF TESTS

1 Number of test	33	35
2 Date of test, 1909	April 13	April 14
3 Method of regulation	Bypass	Bypass
4 Blast pressure, lb	27.3	27.7
5 R.p.m. of engine	54.45	58.62
6 Gas per hr., standard conditions, cu. ft	279,512	325,429
7 Gas per hr., test conditions, cu. ft	297,170	327,501
8 B.t.u. per cu. ft., standard conditions	90.054	87.721
9 B.t.u. per cu. ft., test conditions	84.7031	87.1661
10 Total B.t.u. in gas per hr	25,171,200	28,546,970
11 I.h.p. of motor cylinders	1945.37	2178.06
12 I.h.p. of air pumps	157.40	203.90
13 I.h.p. of gas pumps	214.86	270.27
14 I.h.p. of blowing cylinder	1330.28	1447.41
15 I.h.p. net	1573.11	1703.89
16 I.h.p. friction	242.83	256.48
17 Gross mechanical efficiency of engine, per cent	87.52	88.22
18 Net mechanical efficiency of engine, per cent	68.38	66.45
19 Cu. ft. gas per i.h.p. hr., standard conditions	143.68	149.41
20 Cu. ft. gas per net h.p. hr., standard conditions	177.68	191.00
21 Cu. ft. gas per blast h.p.hr., standard conditions	210.12	224.84
22 B.t.u. per i.h.p-hr	12,939	13,107
23 B.t.u. per net h.p-hr	16,001	16,754
24 B.t.u. per blast h.p-hr	18,922	19,723
25 Efficiency per i.h.p., per cent	19.67	19.42
26 Efficiency per i.h.p., per cent	15.91	15.29
27 Efficiency per blast h.p., per cent	13.45	12.90
28 Dilution coefficient	1.947	2.1732
29 Potential heat in exhaust per hr., B.t.u	10,106,760	9,909,840
30 Heat absorbed by jacket water per hr., B.t.u	4,880,850	3,815,270
31 Sensible heat in exhaust, etc., per hr. by difference, B.t.u	5,323,710	9,277,765

DISTRIBUTION OF TOTAL HEAT

32 Delivered to the blast, per cent	13.45	12.90
33 Pump work, per cent	3.76	4.13
34 Friction, per cent	2.46	2.39
35 Absorbed by jackets, per cent	19.39	13.37
36 Incomplete combustion, per cent	39.79	34.71
37 Balance by difference, per cent	21.15	32.50

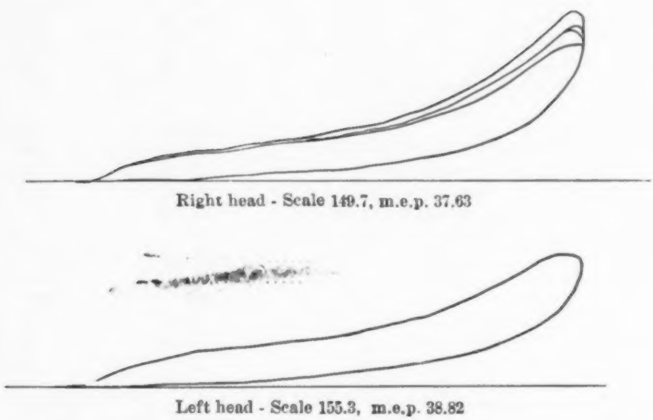


FIG. 63a AVERAGE MOTOR DIAGRAM—TEST 37—5 LB. BLAST

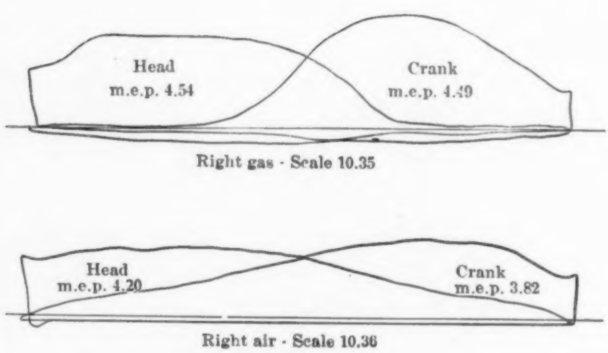


FIG. 63b AVERAGE PUMP DIAGRAM—TEST 37—5 LB. BLAST

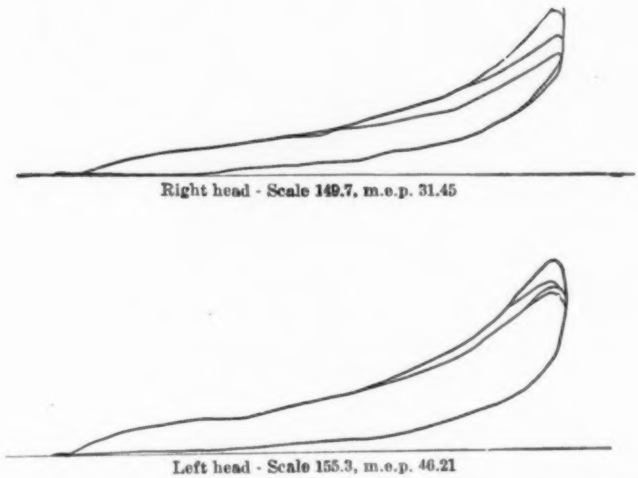


FIG. 64a AVERAGE MOTOR DIAGRAM—TEST 28—10 LB. BLAST

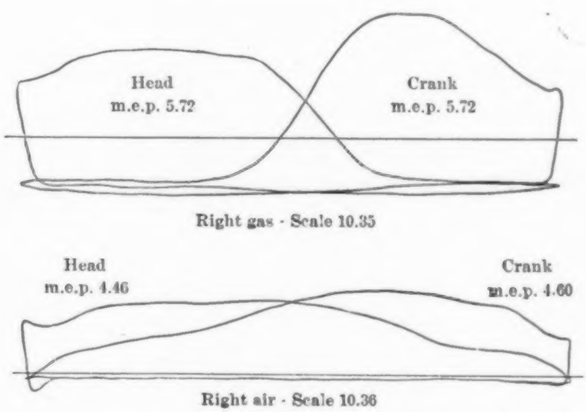
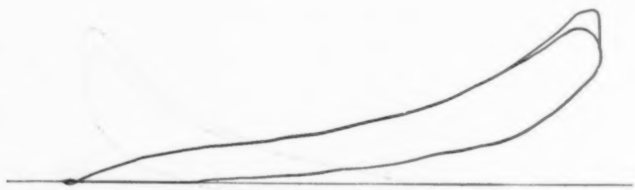


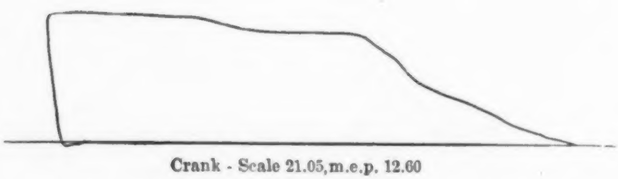
FIG. 64b AVERAGE PUMP DIAGRAM—TEST 28—10 LB. BLAST.

Right head - Scale 149.7, m.e.p. 44.15



Left head - Scale 155.3, m.e.p. 42.35

FIG. 65a AVERAGE MOTOR DIAGRAM—TEST 30—15 LB. BLAST



Crank - Scale 21.05, m.e.p. 12.60

FIG. 65b AVERAGE COMPRESSOR DIAGRAM—TEST 30—15 LB. BLAST

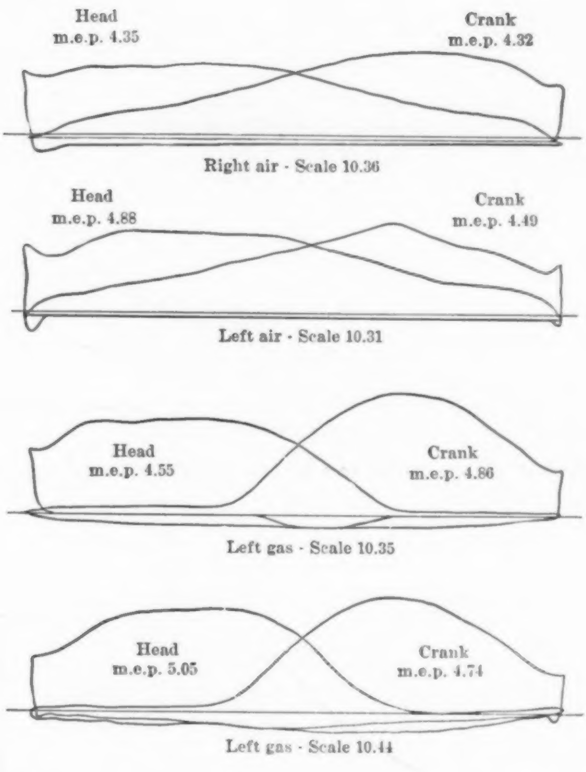
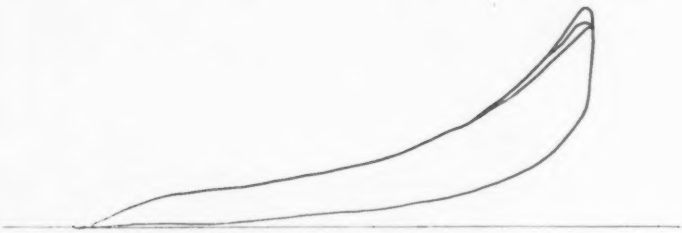
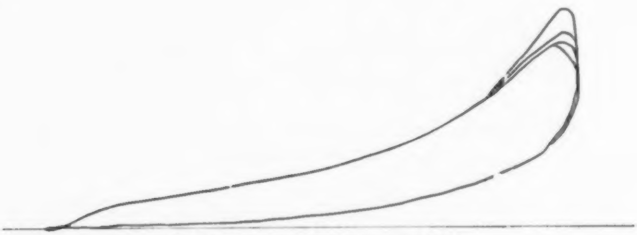


FIG. 65c AVERAGE PUMP DIAGRAM—TEST 30—15 LB. BLAST

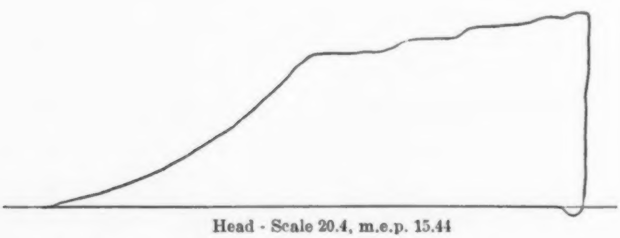


Right head - Scale 149.7, m.e.p. 48.92



Left head - Scale 155.3, m.e.p. 52.63

FIG. 66a AVERAGE MOTOR DIAGRAM—TEST 32—20 LB. BLAST



Head - Scale 20.4, m.e.p. 15.44

FIG. 66b AVERAGE COMPRESSOR DIAGRAM—TEST 32—20 LB. BLAST

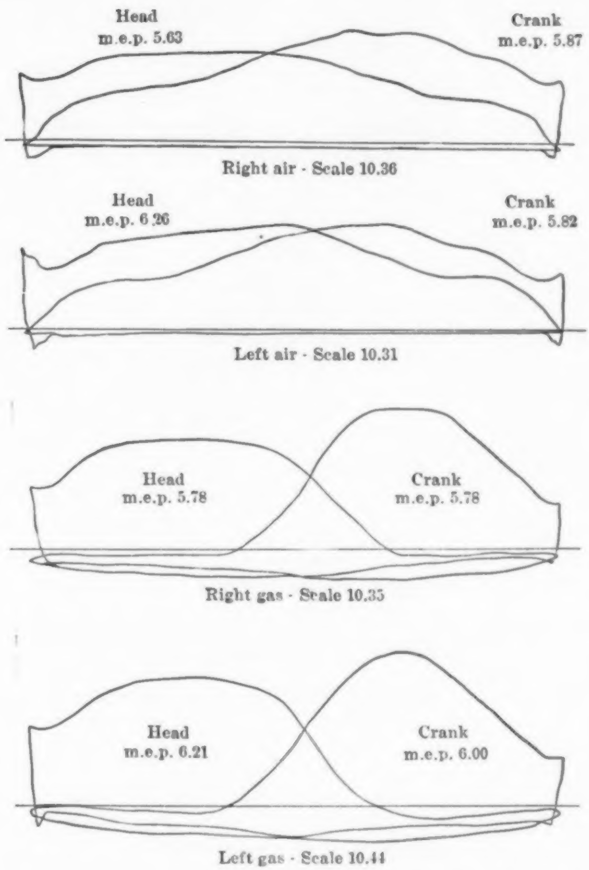


FIG. 66c AVERAGE PUMP DIAGRAM—TEST 32—20 LB. BLAST

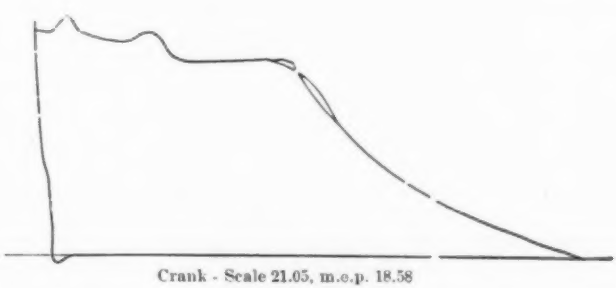
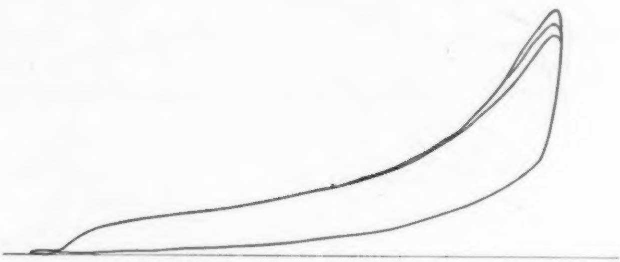
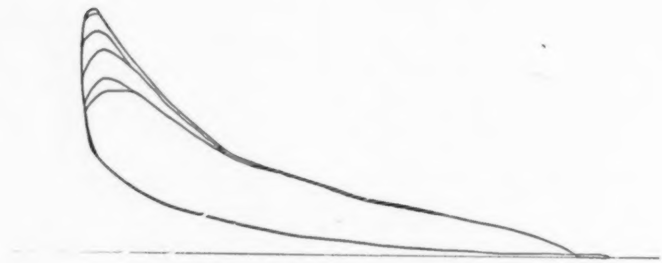


FIG. 67a AVERAGE COMPRESSOR DIAGRAM—TEST 35—25 LB. BLAST

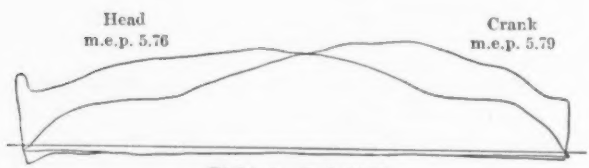


Right head - Scale 149.7, m.e.p. 52.14

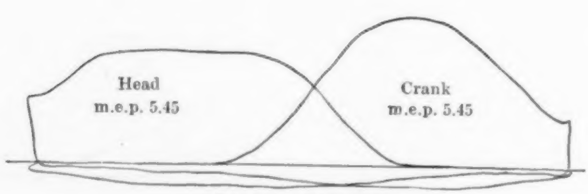


Left crank - Scale 161.9, m.e.p. 58.96

FIG. 67*b* AVERAGE MOTOR DIAGRAM—TEST 35—25 LB. BLAST



Right air - Scale 10.36



Right gas - Scale 10.35

FIG. 67*c* AVERAGE PUMP DIAGRAM—TEST 35—25 LB. BLAST

GENERAL NOTES

AMERICAN SOCIETY OF CIVIL ENGINEERS

The American Society of Civil Engineers has commenced its regular bimonthly meetings for the season of 1910-1911. At the gathering of October 5, E. G. Hopson, member of the society, presented a paper on the Tieton Canal; and on October 19, W. F. Strouse, member of the society, presented The Reconstruction of the Passenger Terminals at Washington, D. C.

In November, The Arch Principle in Engineering and Esthetic Aspects, and its Application to Long Spans, by C. R. Grimm, member of the society, will be discussed at the meeting on the first Wednesday evening in the month; and The Failure of the Yuba River Débris Barrier and the Efforts made for its Maintenance, by H. H. Wadsworth, member of the society, on the evening of the third Wednesday.

AMERICAN INSTITUTE OF MINING ENGINEERS

Plans for the Canal Zone meeting of the American Institute of Mining Engineers, to be held October 21-November 15, 1910, are proceeding satisfactorily and a large attendance is anticipated. Among the papers announced for presentation and discussion, probably on board ship en route to Panama, are Manganese Ore in Unusual Form, by William P. Blake; Crushing Machines for Cyanide Plants by Mark R. Lamb of Milwaukee; Labor-Saving Appliances in the Assay-Laboratory, by Edward Keller of Perth Amboy, N. J.; The Limit of Fuel Economy in the Blast-Furnace, by N. M. Langdon of Mancelona, Mich.; Dry Washing for Placer Gold in Sonora, by J. W. Richards, of Spokane, Wash.; Recent Developments in the Undercutting of Coal by Machinery, by E. W. Parker, Washington, D. C.; The Laws of Intrusion, by Blamey Stevens, Valdez, Alaska; Tests of an Ilgner Electric Hoist, by R. R. Seeber, Winona, Mich.; Bibliography to Accompany Paper on Electric Mine Hoists, by D. B. Rushmore, Mem.Am.Soc.M.E., and K. A. Pauly, Schenectady, N. Y.; Notes on Copper Blast-Furnace Tops, by N. H. Emmons, Copperhill, Tenn.; Mining in Nicaragua, by F. Lane Carter, Chicago, Ill.; Report of a Committee on Uniform Mining Laws for Prevention of Mine Accidents, by W. R. Ingalls, J. Parke Channing, James Douglas and John Hays Hammond, Mem.Am.Soc. M.E., New York, and James R. Finlay, Goldfield, Nev.; The Solid Non-Metallic Impurities in Steel, by Henry D. Hibbard, Mem.Am.Soc.M.E., Plainfield, N. J.; Theory of Dust Explosions, by Audley H. Stow, Maybeury, W. Va.; The Gold Fields of French Guiana and the New Method of Dredging, by A. F. J. Bordeaux, Thonon-Les-Bains, Savoie, France; The Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold Deposits in the United States, by William H. Emmons of Chicago.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The American Institute of Electrical Engineers held their first meeting of the year on Friday evening, October 14, at 8 p.m. in the Engineering Societies Building, New York. A paper was presented on Potential Strength in Dielectrics, by H. S. Osborne, of the American Telephone and Telegraph Company, and Prof. Harold Pender, of Massachusetts Institute of Technology.

On the invitation of the institute a public meeting at which all members of the engineering profession were welcomed was held on Monday evening, October 17, in the Engineering Societies Building. Rapid Transit Requirements of Greater New York, the subject for discussion, was informally presented by F. J. Sprague, Past-President A.I.E.E., and Chairman of the Railway Committee of the institute, in a paper covering the general facts pertaining to routes, construction and equipment of existing and proposed lines.

COURSES IN ARCHITECTURE IN ENGINEERING SOCIETIES BUILDING

Columbia University extension courses in Architecture are being given this year in the Engineering Societies Building, 29 West 39th Street, each weekday evening except Saturday. Three of the courses, mathematics, the history of architecture, and construction; are designed for students who have not had training, while the remainder are those of the first year of the School of Architecture and will count toward the diploma and degree in architecture for those who have passed the entrance examinations.

NATIONAL IRRIGATION CONGRESS

The 18th National Irrigation Congress, held in Pueblo, Colorado, in the Mineral Palace, opened on September 26 with an industrial parade. At the first session, called to order at 2.30 p.m., welcome was extended to the delegates by the Governor Shafroth of Colorado, and the Mayor of Pueblo, Hon. A. L. Fugard. Hon. B. A. Fowler, President of the Congress, responded, and Hon. Alva Adams, Former Governor of Colorado, gave an address on Colorado, Conquest and Conservation. Following an informal reception in the evening, Hon. William J. Bryan of Nebraska spoke on Irrigation and National Development. Tuesday morning was devoted to the consideration of Irrigation by Private Enterprise, with addresses by Hon. Frank C. Goudy, former president of the Congress, by Hon. John M. Wilson, Norman E. Webster, Jr., W. G. DeCelle, Dr. B. L. Jefferson, H. L. Moody, and Hon. George E. Barstow; and in the afternoon Hon. F. H. Newell, R. P. Teele, Gen. B. J. Viljoen, S. H. Lea, Hon. John A. Martin and Hon. John Fairweather spoke upon Public Irrigation. William E. Smythe addressed the evening meeting on The New Gospel: A Little Land and a Living. On Wednesday, W. K. Kavanaugh, Hon. Frank H. Short, Judge Joseph H. Kibbey, Judge George H. Hutton, Prof. E. B. House and James Cosgrove, spoke upon Water Equities; while in the afternoon, Irrigation Agriculture was discussed, with addresses by Albert F. Potter, Ernest Knabel, Dr. W. J. McGee, Col. E. J. Watson, Aaron Gove and Hon. Horace T. DeLong. An illuminated parade took place in the even-

ing. The session of Thursday morning was given up to foreign representatives who brought messages from Austria-Hungary, Australia, Germany, Russia, Canada, British India, and Chili. General Policies were considered in the afternoon, on which occasion Mrs. H. L. Hollister, Hon. Gifford Pinchot, Hon. H. H. Eddy, and Hon. Francis J. Heney addressed the meeting. Problems of Irrigation Practice were discussed on Thursday evening by Prof. Samuel Fortier, Prof. W. B. Gregory, Mem.Am.Soc.M.E., and F. M. Webster. The concluding day of the Congress, Friday, Sept. 30, was devoted to the Governors' Session and to a business meeting at which Hon. B. A. Fowler was re-elected president for the ensuing year, and Arthur Hooker of Spokane chosen secretary.

The Society was represented at these meetings by C. H. Williams of Denver, Colo.

ENGINEERS CLUB OF ST. LOUIS

At the regular meeting of the Engineers Club of St. Louis held on October 5 in the club rooms, J. W. Woermann, Assistant Engineer, Western Division, U. S. A., presented a paper entitled The Deep Waterway—St. Louis to Cairo, giving a review of seven plans suggested for securing a 14-foot depth of channel in the Mississippi River.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS

The 17th annual convention of the American Society of Municipal Improvements was held in the Chamber of Commerce rooms, Erie, Pa., October 11-14. Among the papers presented were European Sewage Disposal, Dr. Rudolph Hering, Mem.Am.Soc. M.E.; Laying Asphalt with a Surface Heated, by B. B. Colburn; Modern Stone Block Pavements, by Wm. A. Howell; The Economics of Modern Highway Engineering, by Prof. A. H. Blanchard; and Taxation, by A. W. Heston. Trips of inspection were made to various points of engineering interest in and about Erie, and an excursion by boat taken through Presque Isle Bay. One of the features of the convention was an exhibit arranged by dealers and manufacturers of municipal appliances.

BROOKLYN ENGINEERS CLUB

William T. Donnelly, Mem. Am. Soc. M.E., presented a paper, illustrated by lantern slides, upon Electrification of the John N. Robins Company, Erie Basin, Brooklyn, N. Y., at the regular meeting of the Brooklyn Engineers Club, on Thursday evening, October 13, 1910, at the Club House in Remsen Street. The paper dealt principally with floating and basin dry dock equipment, compressed air, shop motors and high tension distribution system. On October 20, an informal library talk was given on the Air Compressor by Snowden Redfield, Associate Editor of the American Machinist, which was illustrated with stereoptican views.

AMERICAN GAS INSTITUTE

The 5th annual meeting of the American Gas Institute was held in the auditorium of the Engineering Societies Building, 29 West 39th Street, New York, October 19-21, 1910. Professional sessions occupied both the opening days, while the last day was devoted to a steamboat excursion. On Wednesday evening the members were the guests of the New York Edison Company at the Electrical Show in progress at Madison Square Garden, where the special exhibit of the company was reserved for the exclusive use of the party until 10 p.m. John W. Lieb, Jr., Mem. Am. Soc. M.E., delivered an address. On Thursday evening a banquet was given at the Hotel Astor for the members of the institute and the visiting ladies were entertained at a theatre party.

Among the papers presented at the business sessions were Manufacture of Balloon Gas in Water Gas Apparatus, by George H. Waring; Construction of a Reinforced Concrete Tank for a Gas Holder, by V. L. Elbert; Apparatus Designed for Remote Control of District Pressure, J. S. Kennedy; A Review of Recent Decisions of the Public Service Commissions which affect Gas Companies, by A. E. Forstall, Mem.Am.Soc.M.E.; and The Public Deceived by Faulty Data and Misleading Analysis of Data, by Dr. A. C. Humphreys, Mem. Am. Soc. M.E.

AMERICAN IRON AND STEEL INSTITUTE

The first formal meeting of the American Iron and Steel Institute Convention was held in the Waldorf-Astoria Hotel, New York City, on October 14. Elbert H. Gary, President of the institute, and Chairman of the United States Steel Corporation, presided at the professional sessions and at the banquet on Friday evening, the principal feature of which was a lecture on the Gary plant of the United States Steel Corporation, given by G. G. Thorp, Mem.Am.Soc. M.E., Vice-President of the Indiana Steel Company. On Saturday, October 15, a tour was made of New York harbor, starting from the New York Central and Hudson River Railroad's pier in the Hudson River, proceeding through New York bay to Staten Island and into Kill von Kull, and returning by the Narrows through the East and Harlem Rivers into the Hudson. Landings were made en route at Ellis Island, the Bush Terminal in South Brooklyn, and the Navy Yard.

On Sunday the members and guests left New York by special train for Buffalo where they visited the plant of the Lackawanna Steel Company; Black Rock, where the mammoth lock is being built for the new ship canal; the power plants at Niagara Falls; and Niagara Gorge. Proceeding to Chicago, the party spent several days there, inspecting the plants of the Indiana Steel Company, the Illinois Steel Company, the McCormick Works of the International Harvester Company, the Pullman Company, the Union Stock Yards, and other places of interest. On October 18 a dinner was given at the Blackstone Hotel at which Judge Gary presided. At Pittsburg, where the party arrived on October 20, trips were made to the Jones and Laughlin Steel Company, the Carnegie Steel Company, the Carnegie Institute and Technical Schools, and the Westinghouse plants; and informal dinners were served on Thursday and Fri-

day evenings at the Hotel Schenley. The final stop of the tour was in Washington, D. C., where the leading event was a reception tendered by President Taft at the White House on October 22. The special train conveyed the party to New York on October 23.

In addition to the members present at the meetings and on the tour, about thirty leading iron and steel masters of Great Britain and Europe were in attendance as guests of honor. The committee in charge of the arrangements for the entire period consisted of E. A. S. Clarke, President of the Lackawanna Steel Company, Chairman; James Farrel, President of the United States Steel Products Company; and John A. Topping, President of the Republic Iron and Steel Company.

AMERICAN BOILER MANUFACTURERS ASSOCIATION

The American Boiler Manufacturers Association held its 22d annual meeting at the Auditorium Hotel, Chicago, on October 10-13, 1910, electing the following officers: President, Col. E. D. Meier, Vice-President Am.Soc. M.E., of New York; Secretary, J. D. Farasey of Cleveland; Treasurer, Jos. F. Wangler of St. Louis. Colonel Meier presided at the professional sessions and at the banquet on Thursday evening. The association appointed a committee to investigate and report at its next meeting on the standardization of boilers, as a result of discussion brought up on this subject. During the meeting a trip was made to the Illinois Steel Company plant at Gary, Indiana.

THE AMERICAN STREET AND INTERURBAN RAILWAY ASSOCIATION

The annual convention of the American Street and Interurban Railway Association was held at Atlantic City, N. J., October 10-14, with headquarters at the Greek Temple, Convention Pier. There were papers read on the following subjects: Creation of Passenger Traffic, J. F. Keys; The Use of Metal Tickets, G. L. Radcliffe; Transfer Laws and Suggested Changes, L. S. Hoffman. Various committees also reported on Passenger Traffic, Interurban Rules, Express and Freight Traffic, City Rules, Transfer and Transfer Information, Training of Transportation Employees, Construction of Schedules and Time Tables, Heavy Electric Traffic and Detail Records: Their Use and Value.

PERSONALS

L. B. Alexander has entered the employ of the Bosch Magneto Co., New York, as assistant chief of department. Until recently, Mr. Alexander was vice-president of the Haggerty Contracting Co., New York.

J. F. Beecher, formerly associated with the Pennsylvania Steel Co., Harrisburg, Pa., as checker of the mechanical department, has accepted a similar position with the Indiana Steel Co., Gary, Ind.

George Berna, formerly president of the Hygeia Ice Co., Ithaca, N. Y., has become identified with the Modern Ice Machinery Co., San Antonio, Tex.

Geo. A. Buvinger has accepted a position with the Allis-Chalmers Co., West Allis, Wis., in the capacity of designing engineer for centrifugal pumps. Mr. Buvinger was recently associated with the D'Olier Engineering Co., Philadelphia, Pa., as hydraulic engineer.

V. Z. Caracristi, formerly general maintenance supervisor in charge of the upkeep on tools, buildings and equipment of the plants of the American Locomotive Co., and assistant machinery supervisor on purchase of new tools and equipment and general betterment and improvement work, has become consulting engineer of the Wheeling and Lake Erie R. R. Co., Massillon, O.

W. Van Alan Clark has accepted a position with the Astoria Light, Heat and Power Co., Astoria, L. I., N. Y., as engineer's assistant. Until recently he was draftsman and inspector of construction work, Matawan, N. J.

Geo. E. Crofoot has become associated with the Browning Engineering Co., Cleveland, O. He was formerly instructor in mechanical engineering at the University of Pennsylvania, Philadelphia, Pa.

Henry D. Fisher, recently associated with the U. S. Glass Co., Pittsburg, Pa., in the capacity of supervising engineer, has become connected with the Fuel Testing Co., Boston, Mass.

Perry J. Freeman, formerly instructor in mechanical engineering at the University of Pennsylvania, Philadelphia, Pa., is now in charge of all the shops of the department of mechanical engineering of the University of Illinois, Urbana, Ill.

Albert W. Jacobi has opened an engineering office in Newark, N. J. He was formerly connected with the Tide Water Oil Co., Bayonne, N. J.

Edward K. Junghans has severed his connection with the Porvenir Sugar Co., San Pedro, S. D., and has accepted the position of chief engineer of the Central Mercedita, Ponce, P. R.

A. G. Kessler, formerly instructor in the department of power engineering, Sibley College, Cornell University, Ithaca, N. Y., has become associated with the engineering department of R. G. Peter's Manufacturing Co., Grand Rapids, Mich.

Morris Knowles, recently chief engineer of the Bureau of Filtration, City of Pittsburg, Pa., has opened offices in the Oliver Building, Pittsburg, Pa., for the practice of general and consulting civil engineering, particularly in the important branches relating to municipal, sanitary and hydraulic work.

L. R. Lemoine, formerly general manager of the N. J. Zinc Co., New York, has been appointed 2nd vice-president of the U. S. Cast Iron Pipe and Foundry Co., with headquarters at Philadelphia, Pa.

Samuel T. Mudge has entered the employ of the Rogers Paper Manufacturing Co., South Manchester, Conn., as superintendent. He was recently instructor in mechanical engineering at the University of Michigan, Ann Arbor, Mich.

Henry S. Otto has become superintendent of the Saurer Motor Trucks, Chicago, Ill. He was formerly identified with Munroe & Co., Paris, France.

Harold L. Pope has accepted a position with the Pope Manufacturing Co., West Works, Hartford, Conn., in the capacity of manager. He was recently identified with the Matheson Motor Car Co., Wilkes-Barre, Pa.

E. Posselt, formerly connected with the St. Louis Portland Cement Works, St. Louis, Mo., as assistant manager, has accepted the position of chief engineer of the Cement Securities Co. of Denver, Colo.

Walter I. Slichter has been appointed professor of electrical engineering at Columbia University, New York. He was until recently associated with the General Electric Co., Schenectady, N. Y., as technical assistant to the vice-president and chief engineer of the company, and also a member of the staff of consulting engineers of the company.

T. Carlile Ulbricht has been appointed instructor in the department of power engineering, Sibley College, Cornell University, Ithaca, N. Y. He was formerly assistant instructor in applied mechanics at Pratt Institute, Brooklyn, N. Y.

Louis R. Valentine, formerly associated with the Charles Warner Co., Phoenixville, Pa., has become identified with the Security Cement and Lime Co., Security, Md.

C. C. Wilcox has accepted a position as assistant to the consulting electrical engineer for Hodenpyl, Walbridge & Co. of New York, with office in Detroit, Mich. Mr. Wilcox was formerly connected with the Michigan Agricultural College, East Lansing, Mich., as foreman of machine shop and instructor in thermodynamics.

William F. Zimmermann, recently located in Spokane, Wash., has become identified with the Pittsburg Testing Laboratory as 2nd vice-president, with headquarters in New York.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am. Soc. M. E.

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———Influence of Temperature on the Fragility of Metals. By M. G. Charpy.

———On the International Researches in Microscopic Examination (etching tests) of Iron. By W. Ast.

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———Methods of Testing Metals and Alloys, Hydraulic Cements and Woods, Clay, Stoneware, and Cement Pipes.

———Methods of Testing the Protective Power of Paints Used on Metallic Structures. By E. Ebert. Annex. Raw and Boiled Linseed Oil. By A. Grittner.

———Model Testing Laboratory Installed and Exhibited During the Fourth Congress of the International Association for Testing Materials, Brussels, 1906.

——Necessity of Modifying the Process Actually Followed in Analysing Cement Mortars and in Sampling them. By M. Maynard.

——New Apparatus for Automatically drawing the Load-Strain Diagram due to Impact. By A. Gagarine.

——New Dynamometer Determination of the Yield-Point as a Test-Method. Description of a Machine for Compression, Tension, and Bending Tests. By A. Gagarine.

——New Method of Testing Magnetic Metals. By L. Fraichet.

——New Weathering Tests with Natural Stones. By M. Gary.

——Normal Consistency of Cement Mortars. By J. Malüga.

——Notes on the Examination of Powdered Asphalt. By Dr. Holde.

——Observations Regarding the Mechanical Examination of Iron by Means of Drop-tests with Notched Bars. By C. J. Snyders.

——Official Report of the Proceedings of the Fourth Congress of the International Association for Testing Materials, 1906.

——Phenomena of Deformation and Rupture in Iron and Mild Steel. By F. Osmond.

——Principles of a Standard Method of Testing Wood. By M. Rudeloff.

——Punching as a Testing Method. By M. L. Baclé.

——Relation of Chemical Composition to the Weathering Qualities of Building Stones; the Influence of Smoke Especially Sulphurous Acid on Building Stones; the Weathering Qualitites of Roofing Slates.

——Relation of Timber-tests to Forest Products. By W. K. Hatt.

——Remarks on the Influence of the Shape of the Saw-Notch in the Present Method of Testing for Fragility. By F. Barbier.

——Report on Impact-tests on Notched Bars. By E. Sauvage.

——Report on Methods of Etching Malleable Iron for the Visual Investigation of Structure; and on the Lessons to be learnt therefrom. By E. Heyn.

——Report on the Progress of Metallography since the Congress at Budapest, 1901. By F. Osmond and G. Cartaud. Supplement. By F. Osmond.

——Report on the Work of Committee 22, Appointed for the Solution of the Unification of Testing Methods. By N. Belelubsky.

——Report on the Work of the Council From the Budapest to the Brussels Congress, 1901–1906. By F. Berger.

——Report on Trials made at La Rochelle on the Action of Sea-Waters on Mortars. By E. Mayer.

——Resistance of Stone to Compression, with Elastic Substances Interposed Between the Surfaces in Compression. By G. S. Pace.

——Results of Trials with Timber Carried out at the Austrian Forestry Testing-Station at Mariabrunn. By G. Janka.

——Significance and Importance of Contraction as a Test for Quality Especially in Estimating the Malleability of Metals. By St. Gallik.

——Simple Method of Adapting the Principle of Automatic Registration to Lever-Testing Machines. By A. Mesnager.

——Study of the Methods of Testing Caoutchouc. By E. Camerman.

——Tests of the Decomposition of Cement Mortars by Sea-Water and Waters Containing Sulphates. By A. Bauchère.

——Tests upon Notched Bars Carried out in the Laboratory de l'Ecole des Ponts et Chaussées, Paris. By M. Mesanger.

——To Establish Methods for Testing Puzzolanas with the object of Determining their Value for Mortars. By G. Herfeldt. Annex. Experiments made in the Laboratoire des Ponts et Chaussées de Boulogne sur Mer with the View of Determining the Methods for Testing Puzzuolanas. By R. Feret.

——To Establish Methods of Inspection and Testing for Determining the Uniformity of Individual Shipments of Iron and Steel. By W. Ast.

——To Establish Uniform Methods of Testing Cast Iron and Finished Castings. By R. Moldenke.

——Transmission of Forces to the Interior of Elastic Solids. By M. Mesnager.

——On the Uniform Nomenclature of Iron and Steel. By H. M. Howe and A. Sauveur.

——Unmittelbare Abbildung der Neutralen Schichte bei Biegung Durchsichtiger Korper in Zirkularpolarisiertem Licht. By O. Hönigsberg.

North-East Coast Institution of Engineers and Shipbuilders. Transactions. Vol. 26. *Newcastle-upon-Tyne*, 1910.

Record of the Special Commission formed by the British Fire Prevention Committee to visit Berlin, Hamburg and Hanover on the Occasion of A Meeting of the German Professional Fire Service Association (Hamburg, 1909). Being a Diary and Notes. Compiled by E. O. Sachs and E. Marsland. (British Fire Prevention Committee.) *London*. Journal No. 5, 1910.

TRADE CATALOGUES

Broderick & Bascom Rope Co., *New York, N. Y.* Automatic loader system of aerial wire rope tramways, 15 pp.

Thos. Carlin's Sons Co., *Pittsburg, Pa.* Shears for rolling mills, forges, scrap yards, etc., 22 pp.; Hoisting engines and derricks, 70 pp.; Grinding machinery, 15 pp.

F. H. Evans, *Brooklyn, N. Y.* "Crescent" Expansion bolts, 12 pp.

H. W. Johns-Manville Co., *Cleveland, O.* J.-M. Roofing Salesman, September 1910, 8 pp.; J.-M. Packing Expert, September 1910, 4 pp.

Link-Belt Co., *Philadelphia, Pa.* Silent chain for power transmission, 40 pp.

Massachusetts State Boiler Board, *Boston, Mass.* Boiler manufacturers authorized to construct Massachusetts standard boiler, 14 pp.

North Western Expanded Metal Co., *Chicago, Ill.* Designing data for reinforced concrete, 48 pp.

Joseph T. Ryerson & Co., *New York, N. Y.* Monthly Journal and Stock List, October, 1910, 144 pp.

Sims Co., *Erie, Pa.* By-Pass open feed water heater, filter, oil separator and receiver. 12 pp.

Underfeed Stoker Co. of America, *Chicago, Ill.* Publicity Magazine, September 1910, 15 pp.; October 1910, 16 pp.

Union Fibre Co., *Winona, Minn.* Linofelt, 64 pp.; Cold storage insulation, 32 pp.

UNITED ENGINEERING SOCIETY

AMERICAN TRADE INDEX. (Domestic Edition.) 1908–1910. *New York, 1910.* Gift of National Association of Manufacturers.

BREAKDOWN CONNECTIONS TO ISOLATED PLANTS. By M. F. McAlpin. *New York, 1910.* Gift of the author.

DEUTSCHER VEREIN VON GAS UND WASSERFACHMÄNNERN. VERHANDLUNGEN. 1891–1901. *München, 1892–1902.*

POOR'S MANUAL OF RAILROADS, 1910. *New York, 1910.*

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the mediun. of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

051 Urgent need of man thoroughly competent on all questions of gear cutting. Must know thoroughly the bevel, spur and worm gear theory and practice and be able to handle men.

052 Experienced general foreman to manage about one hundred men in the manufacture of single, duplex and power pumps. Location Ohio.

053 Engineer to take charge of construction. Must have some knowledge of gas engine and electrical practice, able to design and superintend new buildings of simple character; growing plant consisting of foundries and machine shops employing 800 hands in town of 18,000 inhabitants in Schuylkill valley, 40 miles from Philadelphia.

054 Wanted, by a New York company, up-to-date, energetic salesman for combustion work. New York territory.

055 Old established manufacturing business needs a business manager, able to take an interest of ten to twenty thousand dollars. Engineering features can be eliminated or separated. Attractive profits have been made for thirty years. Present manager would give part time for one or two years when needed.

056 Exceptional opportunity is offered to a mechanical engineer of executive ability who will invest a few thousand dollars and have tbe management of a company manufacturing a perforated steel band drive (Patented), capable of limitless use in the textile and many other trades. This company will also manufacture and market machinery improved and simplified by use of such band device for the textile trades.

MEN AVAILABLE

127 Sales engineer, seven years varied engineering experience and six years in selling end. Would consider position where knowledge of machinery and mill supply trade of the United States and Canada is essential. Experience in correspondence and proper design of selling contracts.

128 Young engineer, married, Junior member, graduate Stevens, with valuable experience in operation end of manufacturing concerns, erection, maintenance and repair of steel mills, decorticating, saw mill, textile, coal handling, and power plant machinery, desires position in executive capacity with first-class concern manufacturing machinery in these or associated lines. Location East or Middle West.

129 Junior member, college graduate, at present holding high executive position would like to affiliate with some large engineering concern. Wide experience in steam, electric and hydraulic work. Particularly familiar with textile machinery. Would consider superintendency of large bleachery.

130 Mechanical engineer and designer. Ten years broad practical experience. Design and construction of hydro-electric power plants, electric railroads, industrial and power plant mechanical equipment, foundations, special mechanical devices and machine design, gas engines and aeronautical work. Technical education; executive ability. Desires position as mechanical engineer or superintendent with gas engines builders. At present employed.

131 Graduate mechanical and electrical engineer, practical mechanic, several years of broad industrial experience, wishes to secure position where energy, ability and "push" are the qualities most desired and recognized. Thoroughly experienced in ice-making and refrigeration. At present located in Southern city. Salary commensurate with importance of position. Permanency preferred and sought.

132 Member, technical education and training, twelve years experience machine, mill and power house design, inspecting and estimating, corresponding, office work, etc. Desires change of position, southern California preferred, but not essential.

133 New York member, age 37, technical graduate, broad experience covering shop-costs, catalog writing, advertising, business corresponding and engineer-salesman. For several years in general charge of sales department of large concern. Now engaged in special line; desires executive position with progressive company, preferably with chance of acquiring an interest.

134 Technical graduate in electrical engineering and manual training school, with additional shop, drafting room and office practice; desires position in office where such experience will be of advantage.

135 Associate, age 32, at present engaged as engineer with large manufac-

turing concern, desires to change. Construction, operation, general engineering and executive experience.

136 Junior, experienced on boiler design, construction and estimating. Technical graduate, familiar with modern boiler shop and foundry methods, good organizer. At present chief draftsman and engineer. Desires similar position or assistant superintendent.

137 Member desires position as superintendent or manager. Technical graduate with wide practical experience in the machine shop, foundry and business. Now employed on staff of a production engineer, but prefers position with fixed residence.

138 Member, technical graduate, charge of large shops as superintendent and manager, also estimating cost systems, correspondence etc., thorough experience in design, construction and economical operation of power and manufacturing plants. Several years experience as sales manager Corliss engines; also as general sales manager water tube boilers. Desires position with chance to secure an interest. Engaged in special work at present but desires permanency.

139 Member, technical graduate, practical mechanic, with wide experience in the design, manufacture and sales of boilers, both water tube and return tubular, self supporting stacks, breechings, tanks, etc., and also design and installation of complete power plants, desires position where above knowledge can be put to best use. Can handle shop, office or sales and desires a permanent position. If connection is mutually satisfactory could invest some money in the company.

140 Junior member, graduate of Massachusetts Institute of Technology, M.E.; four years in practical shop work, general drafting and minor executive; desires position as draftsman with consulting engineers or as assistant to superintendent of industrial plant.

141 Internal combustion engine salesman and manager, 34 years of age. Eight years experience, particularly in the oil engine branch of business; desires position with aggressive, growing concern, on developing or building oil engines preferred. Suitable references furnished.

142 M.E. Virginia Polytechnic Institute and Cornell, at present with structural steel concern as draftsman, desires position with consulting and contracting engineers; experience in machine tool design, steel mill and blast furnace construction.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ADAMS, Thomas D. (Junior, 1906), Werner & Pfleiderer, Saginaw, Mich., and *for mail*, Southport, Conn.

ALEXANDER, Ludwell Brooke (Junior, 1905), Asst. Ch. of Dept., Bosch Magneto Co., 223 W. 46th St., and *for mail*, Cliffwood Court, 179th St. and Ft. Washington Ave., New York, N. Y.

APPLETON, Henry W. (Junior, 1906), Mech. Supt., Passaic Print Wks., and *for mail*, 243 Van Houten Ave., Passaic, N. J.

ARMSTEAD, Frank C. (1906), 1085 E. 17th St., Brooklyn, N. Y.

BARNES, Arthur F. (Junior, 1910), Instr. in Mech. Engrg., Univ. of Pa., and *for mail*, 5229 Greenway Ave., Philadelphia, Pa.

BEECHER, J. F. (Associate, 1908), Checker, Indiana Steel Co., and *for mail*, 535 Jefferson St., Gary, Ind.

BERNA, George (1906), Modern Ice Machine Co. San Antonio, Tex.

BEVIN, Sydney (Junior, 1910), Asst. Fdy. Foreman, Mfr. Rider & Ericsson Hot-Air Pumps, Walden, Orange Co., N. Y.

BIXLER, Harry Z. (1907), Ch. Engr., Youngstown Steel Co., and *for mail*, 213 Arlington St., Youngstown, O.

BLUMGARDT, Isaac E. (Associate, 1908), Maxwell-Briscoe Motor Co., North Tarrytown, N. Y.

BRESLOVE, Joseph (Junior, 1906), Mech. Engr., Nivison-Weiskopf Co., and *for mail*, 2 Lee Court, Avondale, Cincinnati, O.

BUVINGER, George A. (1901; 1904), Designing Engr., Centrifugal Pumps, Allis-Chalmers Co., West Allis, and *for mail*, University Club, Milwaukee, Wis.

CARACRISTI, Virginius Z. (1904; 1907), Cons. Engr., Wheeling & Lake Erie R. R. Co., Massillon, O.

CARPENTER, Charles U. (1907), Pres., Herring-Hall-Marvin Safe Co., Hamilton, O.

CLANCY, Geo. W. (Associate, 1909), Pres., Globe Chem. Co., 68 Devonshire St., Boston, Mass., and *for mail*, 20 Manning Blvd., Albany, N. Y.

CLARK, W. Van Alan (Junior, 1910), Engrs'. Asst., Astoria Light, Heat & Power Co., Astoria, L. I., N. Y.

COLLINS, B. R. T. (1891; 1901), Engr., Stone & Webster Engrg. Corp., 147 Milk St., Boston, and *for mail*, 29 Oxford Rd., Newton Centre, Mass.

COLWELL, James V. V. (1903), Life Member; Mgr., N. E. Dept., Heine Safety Boiler Co., 176 Federal St., and 201 Devonshire St., Boston, Mass.

CORP, Charles I. (Junior, 1904), 504 W. Johnson St., Madison, Wis.

CORREA, William Howard (Junior, 1910), Asst. M. M., Standard Oil Co., Pratt Wks., Brooklyn, and *for mail*, 640 W. 139th St., New York, N. Y.

CROFOOT, George Emerson (Junior, 1907), Browning Engrg. Co., Cleveland, and *for mail*, 914 Mars Ave., Collinwood, O.
DAVIS, Thomas B. (1907; 1909), Forrest City, Ark.
DELANY, Chas H. (1907), 2946 Pierce St., San Francisco, Cal.
DODDS, William B. (Junior, 1907), 31 Everett St., Cambridge, Mass.
DOUGLASS, Wm. M. (1884), Treas., Globe Real Estate Co., 18 S. 6th St., Allentown, Pa.
EMSWILER, John Edward (Junior, 1908), Instr., Mech. Engrg., Univ. of Mich., New Engrg. Bldg., Ann Arbor, Mich.
FISHER, Henry Donald (Junior, 1907), Fuel Testing Co., 220 Devonshire St., Boston, Mass.
FRANKENBERG, George T. (Associate, 1907), Mech. Engr., Ralston Steel Car Co., and *for mail*, 1191 Oak St., Columbus, O.
FREEMAN, Perry John (Junior, 1908), Mech. Engrg. Dept., Univ. of Illinois, Urbana, Ill.
GARDNER, Henry (Junior, 1904), Asst. Supt. of Apprentices, N. Y. Central Lines, 1526 Grand Central Terminal, New York, N. Y.
HARDING, Adalbert (Junior, 1898), 24 Langdon St., Cambridge, Mass.
HART, Rogers Bonnell (Associate, 1907), Y. M. C. A., East Liberty, Pittsburg, Pa.
HOLBROOK, Percy (1900), V. P., Rail Joint Co., 185 Madison Ave., New York, N. Y.
HOLMES, Arthur (Junior, 1904), Asst. Engr., H. H. Franklin Mfg. Co., and *for mail*, 219 Lancaster Ave., Syracuse, N. Y.
JACOBI, Albert W. (1885), Life Member; Cons. Engr., 192 Market St., Newark, N. J.
JOHNSON, Louis L. (1908), 420 Law Bldg., Indianapolis, Ind.
JONES, John T. (1890), Iron Mountain, Mich.
JUNGHANS, Edward K. (1908), Ch. Engr., Central Mercedita, Ponce, P. R.
KATZENSTEIN, Martin L. (Junior, 1903), Mgr., Marine Dept., Internatl. Steam Pump Co., 115 Broadway, and *for mail*, 52 E. 81st St., New York, N. Y.
KENYON, Alfred Lewis (1904), 144 Edgewood Ave., Atlanta, Ga.
KESSLER, Armin Geo. (Junior, 1909), Engr. Dept., R. G. Peter's Mfg. Co., and *for mail* 159 Ransom St., Grand Rapids, Mich.
KIRCHHOFF, Charles (1882), Rhineland Court, 244 Riverside Drive, New York, N. Y.
KIRKUP, Joseph P. (Junior, 1908), Engrg. Dept., L. J. Wing Mfg. Co., 90 West St., New York, N. Y.
KNOWLES, Morris (1907), 2548 Oliver Bldg., Pittsburg, Pa.
KNOX, S. L. Griswold (1892; 1901), M. Burr, Jr. & Co., 20 Broad St., New York, N. Y.
LAFORE, John Armand (1904), Sales Mgr., D'Olier Engrg. Co., Philadelphia, and *for mail*, Cynwyd, Pa.
LAND, Frank (1900), Secy. and Treas., Land-Wharton Co., 912 Pa. Bldg., Philadelphia, and *for mail*, Montgomery Inn, Bryn Mawr, Pa.
LANE, J. S. (1882), M. E., Engineer Co., Cons. and Contr. Engrs., 50 Church St., New York, and 283 Highland Blvd., Brooklyn, N. Y.
LANGE, Heinrich Bartels (Junior, 1910), Hillcrest, Summit, N. J.

LEE, Robert E. (Junior 1907), Mech. Engr., 804 Monroe St., Ann Arbor, Mich.

LEMOINE, L. R. (Associate, 1887), 2nd V. P., U. S. Cast Iron Pipe & Fdy. Co., 1421 Chestnut St., Philadelphia, Pa.

LEMON, John C. (1902), Mech. Engr., Grand Opera House Bldg., and *for mail* 2844 Linwood Ave., Cincinnati, O.

LOCKWOOD, James Fred (1889; 1907), Mgr., Security Elev. Safety Co., 126 W. 18th St., New York, and *for mail,* 678 McDonough St., Brooklyn, N. Y.

McDEVITT, Frank J. (Junior, 1906), Elliott Co., and Liberty Mfg. Co., Pittsburg, Pa., and *for mail,* 1201 Manhattan Bldg., Chicago, Ill.

MAGIN, Frank W. (Junior, 1907), Allis-Chalmers Co., Milwaukee, Wis.

MALLORY, Charles K. (1907), Engr., Constr. and Maintenance, Solvay Process Co., and *for mail,* 1027 James St., Syracuse, N. Y.

MARSHALL, Wm. Crosby (1901; 1909), Asst. Prof. Descriptive Geom. and Drawing, 114 Winchester Hall, S. S. S., Yale Univ., and *for mail,* 137 Wall St., New Haven, Conn.

MERRILL, Albert S. (Junior, 1903), 509 High St., Easton, Pa.

MORGAN, John R. (1901), Mech. Engr., Box 268, Gary, Ind.

MOXHAM, Egbert (Junior, 1906), Mgr., Pulp Key Dept., E. I. du Pont de Nemours Co., and *for mail,* 1500 Pa. Ave., Wilmington, Del.

MUDGE, Samuel Tenney (Junior, 1910), Supt., Rogers Paper Mfg. Co., South Manchester, Conn

NAYLOR, John Samuel (1887), Prop., Peoples' Wks., Front St. and Girard Ave., and 201 West Chester Ave , Chestnut Hill, Philadelphia, Pa.

OTTO, Henry S. (Junior, 1909), Supt., Saurer Motor Trucks, 301-315 N. Halsted St., Chicago, Ill.

OVIATT, David B. (1891), Asst. Engr., Bd. of Water Supply, City of N. Y., 147 Varick St., and 172 W. 109th St., New York, N. Y.

PALMER, Cortlandt E. (1895), 137 E. 19th St., New York, N. Y.

PERCY, Earl N. (Junior, 1907), Mech. Engr., Standard Oil Co., and Transportation Club, Palace Hotel, San Francisco, Cal.

PINNER, Seymour W. (Junior, 1909), Edison Ill. Co. of Detroit, 18 Washington Ave., Detroit, Mich.

POPE, Harold L. (Junior, 1905), Mgr., Pope Mfg. Co., West Wks., Hartford, Conn.

POSSELT, Ejnar (Junior, 1907), Ch. Engr., Cement Securities Co., Denver, and *for mail,* care Colorado Portland Cement Co., Portland, Colo.

SANDO, Will J. (1899), Manager, 1908-1911; Milwaukee Club, Milwaukee, Wis.

SEARLE, Wilbur C. (Junior, 1909), Heald Mch. Co., and *for mail,* 23 Dover St., Worcester, Mass.

SHEPERDSON, John Wm. (Associate, 1908), Steam Engr., Cambria Steel Co., and *for mail,* 126 Tioga St., Westmont, Johnstown, Pa.

SLATER, Alpheus B. (1891), Slocums, R. I.

SLICHTER, Walter I. (Junior, 1902), Prof. Elec. Engrg., Columbia Univ., New York, N. Y.

SMITH, Edward Jos. (1904), 30 Church St., New York, and 1099 Gates Ave., Brooklyn, N. Y.

TAYLOR, Frank H. (1908), 44 E. 82d St., New York, N. Y.

THOMPSON, Edward P. (1884), M. E., Registered Pat. Atty. and Cons. Engr., 34 E. 32d St., New York, N. Y.

ULBRICHT, T. Carlile (Junior, 1908), Instr., Dept. of Power Engrg., Sibley College, Cornell Univ., Ithaca, N. Y.

VALENTINE, Louis Rossiter (Junior, 1907), Security Cement & Lime Co., Security, and *for mail*, 38 Wayside Ave., Hagerstown, Md.

WADLEIGH, George R. (1907), Hotel Berlin, St. Louis, Mo.

WEBSTER, Lawrence Burns (Junior, 1910), 15,440 Turlington Ave., Harvey, Ill.

WEGG, David S., Jr. (Junior, 1909), Telluride House, Ithaca, N. Y.; also 16 E. Ontario St., Chicago, Ill.

WETMORE, Charles P. (1901), 615 Merrill Bldg., and 518 Astor St., Milwaukee, Wis.

WILCOX, C. C. (Junior, 1905), Asst. to Cons. Elec. Engr., Hodenpyl, Walbridge & Co., 1004 Majestic Bldg., Detroit, Mich.

WILLIAMS, George W. (1904; 1907), 67 Stanley Ave., Hamilton, Ont., Canada.

WINGER, Stanley D. (Junior, 1904), Sales Engr., Green Engrg. Co., 39 Jackson Blvd., and 4447 Indiana Ave., Chicago, Ill.

YARYAN, Homer T. (1892), V. P., Yaryan Naval Stores Co , Gulfport, Miss.

YOUNG, E. R. (Junior, 1900), Cuyahoga Falls, O.

ZIMMERMANN, Wm. F. (1884), 2nd V. P., Pittsburgh Testing Lab., Rm. 386, 50 Church St., New York, N. Y.

NEW MEMBERS

CARBO, Luis Alberto (Junior, 1909), Ch. Engr., Guayaquil Sewer and Water Bd., P. O. Box 15, Guayaquil, Ecuador, S. A.

COBB, Stephen Prentis (Associate, 1910), Albany Southern R. R., Albany, N. Y.

FULLER, George W. (1910), Hering & Fuller, 170 Broadway, New York, N. Y.

WILSON, Robert Alexander (Junior, 1910), Carnegie Steel Co., Ohio Wks., Youngstown, O., and Constr. Engr., Snow Steam Pump Wks., Buffalo, N. Y.

PROMOTIONS

HAWLEY, Wm. Parker (1903; Associate, 1910), Instr., Mech. Drawing, Lewis Inst., Chicago, and 320 N. 64thAve., Oak Park, Ill.

DEATHS

BELSLEY, Clay, September 3, 1910.

JONES, Washington, July 30, 1910.

WHEELER, Frederick Meriam, September 15, 1910.

WILKINSON, Alfred, August 30, 1910.

GAS POWER SECTION

CHANGES OF ADDRESS

ADDIS, Roscoe D. (Affiliate, 1908), Mgr., Gas Eng. Dept., Jas. Beggs & Co., 109 Liberty St., and *for mail,* 215 Audobon Ave., The Brighton, New York, N. Y.

CARACRISTI, Virginius Z. (1909), Mem. Am. Soc. M. E.

FISKE, Geo. Wallace (Affiliate, 1909), 1429 Polk St., Topeka, Kan.

JAMES, Frederick Conway (Affiliate, 1910), present address unknown.

JOHNSON, Louis L. (1910), Mem. Am. Soc. M. E.

MACNEILL, M. B. (Affiliate, 1909), Hyd. Engr., Watson-Stillman Co., Aldene, Union Co., and 110 Littleton Ave., Newark, N. J.

PERCY, Earl N. (1909), Mem. Am. Soc. M. E.

SMITH, Bronson H. (Affiliate, 1908), Asst. Engr., Westinghouse, Church, Kerr & Co., 10 Bridge St., New York, N. Y.

STEVENS, Henry R. (Affiliate, 1909), Cons. Engr., 4645 First Ave., N. E., Seattle, Wash.

ULBRICHT, T. C. (1908), Mem. Am. Soc. M. E.

VINCENT, Jay Carter (Affiliate, 1909), Asst. Engr., Power and Equip., Twin City Rapid Transit Co., and *for mail,* 3100 James Ave., S., Minneapolis, Minn.

NEW MEMBERS

FITCH, Charles L. (Affiliate, 1910), Engr., 253 Throop Ave., Brooklyn, N. Y.

PORTER, Harold Ernest (Affiliate, 1910), Engr., Tait Producer Co., New York, and *for mail,* 254 Decatur St., Brooklyn, N. Y.

STUDENT BRANCHES

CHANGES OF ADDRESS

ALLEN, Carlton H. (Student, 1910), Glen Park, Jefferson Co., N. Y.
BARRETT, Sampson A. (Student, 1910), 13 Monroe Pl., Brooklyn, N. Y.
BOLGIANO, J. R. (Student, 1909), Taylor Iron & Steel Co., High Bridge, N. J.
BRENEMAN, Paul E. (Student, 1910), 717 W. Poplar St., York, Pa.
BUSH, Charles A. (Student, 1910), Lexington, Neb.
BUTLER, W. C. M. (Student, 1910), Thurston Ave., Ithaca, N. Y.
BUYERS, Donald E. (Student, 1910), 1202 W. 3d St., Sterling, Ill.
CARLSON, Chas. A. (Student, 1910), 905 S. Busey Ave., Urbana, Ill.
CARNAHAN, O. A. (Student, 1909), 5523 Chancellor St., Philadelphia, Pa.
COBB, P. L. (Student, 1909), 38 Schermerhorn St., Brooklyn, N. Y.
COLEMAN, Wm. F. (Student, 1909), 4300 Park Ave., Chicago, Ill.
DEXTER, Robert L. (Student, 1910), 39 Pleasant Pl., Athol, Mass.
FRAMBACH, Frederick S. (Student, 1910), 292 Manhattan Ave., New York, N. Y.
GILBERT, F. B. (Student, 1909), 4759 Calumet Ave., Chicago, Ill.
GODFREY, Paul S. (Student, 1910), 198 E. Mil Ave., Wauwatosa, Wis.
HAM, C. W. (Student, 1910), 109 W. Buffalo St., Ithaca, N. Y.
HENWOOD, P. E. (Student, 1909), 4631 Calumet Ave., Chicago, Ill.
HUNTINGTON, C. S. (Student, 1909), 509 E. John St., Champaign, Ill.
JOHNSON, Charles A. (Student, 1910), 31 Orange St., Waltham, Mass.
JONAS, M. R. (Student, 1909), 205 Williams St., Ithaca, N. Y.
KASTLER, E. L. (Student, 1910), Baker Mfg. Co., Evansville, Wis.
KEOWN, B. L. (Student, 1909), Association Hall, Champaign, Ill.
KREIDLER, D. W. (Student, 1909), 1007 S. Wright St., Champaign, Ill.
LANGWILL, John S. (Student, 1910), 740 Langdon St., Madison, Wis.
LUND, J. C. (Student, 1909), 609 S. Coler Ave., Urbana, Ill.
MATTHEWS, Robertson (Student, 1910), 617 N. Cayuga St., Ithaca, N. Y.
MEYER, Richard C. (Student, 1909), 710 Thurston Ave., Ithaca, N. Y.
MOSCHEL, H. (Student, 1909), Republic Iron & Steel Co., Moline, Ill.
NORWOOD, C. T. (Student, 1909), 215 W. Cypress Ave., Redlands, Cal.
SMITH, Donald F. (Student, 1910), 411 Dryden Rd., Ithaca, N. Y.
SPONSEL, J. G. (Student, 1909), 307 E. Daniel St., Champaign, Ill.
VAUGHAN, L. L. (Student, 1910), Hartley Hall, Columbia Univ., New York, N. Y.
WATROUS, Russell W. (Student, 1910), 127 Dryden Rd., Ithaca, N. Y.
WESTLUND, A. F. (Student, 1909), 110 E. Green St., Champaign, Ill.

COMING MEETINGS

NOVEMBER—DECEMBER

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

ALABAMA LIGHT AND TRACTION ASSOCIATION
November 21–23, annual convention, Anniston, Ala. Secy., Geo. S. Emery.

AMERICAN INSTITUTE OF MINING ENGINEERS
October 21–November 15, special meeting, Canal Zone, S.A. Secy., Dr. Joseph Struthers, 29 W. 39th St., New York.

AMERICAN MATHEMATICAL SOCIETY
December 28–29, annual meeting, Columbia University, New York. Secy., F. N. Cole.

AMERICAN RAILWAY ASSOCIATION
November 16, semi-annual meeting, St. Louis, Mo. Secy. W. F. Allen, 24 Park Pl., New York.

THE AMERICAN SOCIETY FOR THE ADVANCEMENT OF SCIENCE
December 27–January 3, Minneapolis and St. Paul, Minn. Secy., L. O. Howard, Smithsonian Institution Washington, D. C.

AMERICAN SOCIETY OF CHEMICAL ENGINEERS
December 8–10, Philadelphia, Pa. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

AMERICAN SOCIETY OF CIVIL ENGINEERS
November 2, 220 W. 57th St., New York. Papers: The Arch Principle in Engineering and Esthetic Aspects and its Application to Long Spans, by C. R. Grimm; November 16, The Failure of the Yuba River Dèbris Barrier and the Efforts made for its Maintenance, by H. H. Wadsworth. Secy., C. W. Hunt.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
November 11, 29 W. 39th, St. New York. Paper: Interpole Synchronous Converters, by B. G. Lamme and F. D. Newbury. Secy., R. W. Pope.

AMERICAN SOCIETY OF REFRIFERATING ENGINEERS
December 5–6, annual meeting, New York. Secy., W. H. Ross, 154 Nassau St.

THE AMERICAN SOCIETY OF SWEDISH ENGINEERS
November 19, 271 Hicks St., Brooklyn, N. Y. Paper: Modern Development of Electric Transformer Design, by H. Pikler. Secy., A. Nilsson.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS
December 12–14, annual convention, New York. Secy., Percy H. Wilson, Land Title Building, Philadelphia, Pa.

ENGINEERS CLUB OF ST. LOUIS
December 7, annual meeting, St. Louis, Mo. Secy. A. S. Langsdorf, Washington University.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS
November 16–23, annual meeting, Washington, D. C. Reports: Powers, Duties and Work of State Railway Commissions, Legislation, Shippers' Claims on Common Carriers, Railway Service and Railway Accommodation, Construction and Operating Expenses of Electric Railways, Simplification of Railway Tariffs, Rates and Rate Making, Uniform Classification, Car Service and Demurrage, Railway Capitalization, Safety Appliances, Grade Crossings and Trespassing on Railroads, Railroad Taxes and Plans for Ascertaining the Fair Value of Railroad Property, Amendment of Act to Regulate Commerce, Delays Attendant upon Enforcing Orders of State Railway Commissions. Secy., Wm. H. Connolly, c/o Interstate Commerce Commission.

NATIONAL ASSOCIATION OF CEMENT USERS
December 12–23, annual convention, New York. President, Richard L. Humphrey, Harrison Building, Philadelphia, Pa.

NATIONAL COMMERCIAL GAS ASSOCIATION
December 5–13, annual convention and exhibition, Mechanics' Hall, Boston, Mass. Papers: Manufacturers' Paper; Industrial Fuel; Illumination; Commercial Man—His Opportunities and Future, Rates, Compensation of Solicitors; The Commercial Department as seen through the Eyes of a Traveling Salesman; Lighting and Fuel Maintenance; Water Heaters; Relations with Customers; Office and Accounting Methods. Secy., Louis Stotz, 29 W. 39th St., New York.

NATIONAL GAS AND GASOLINE ENGINE TRADES ASSOCIATION
December 12–15 annual meeting, Racine, Wis. Secy., A. Stritmatter, Cincinnati, O.

NATIONAL MUNICIPAL LEAGUE
November 14–18, annual meeting, Buffalo, N. Y. Secy., Clinton Rogers Woodruff, North American Bldg., Philadelphia, Pa.

NATIONAL SOCIETY FOR PROMOTION OF INDUSTRIAL EDUCATION
December 1–3, annual convention. Secy., J. C. Monaghan, 20 W. 44th St., New York.

NEW JERSEY SANITARY ASSOCIATION
December 2–6, annual meeting, Lakewood, N. J. Secy., J. A. Exton, 75 Beech St., Arlington.

NEW YORK CEMENT SHOW
December 14–20, first annual convention, Madison Square Garden, New York. Under the management of the Cement Producers Company, 115 Adams St., Chicago, Ill.

NORTHERN RAILWAY CLUB
November 26, Duluth, Minn. Secy., C. L. Kennedy, C. M. & St. P. Ry., 401 West Superior St.

OHIO SOCIETY OF MECHANICAL, ELECTRICAL AND STEAM ENGINEERS
November 18–19, annual meeting, Springfield, O. Secy., F. E. Sanborn, Ohio State University, Columbus.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
November			
2	Wireless Institute	S. L. Williams	7.30 p.m.
3	Blue Room Engineering Society	W. D. Sprague	8.00 p.m.
9	American Institute Mechanical Engineers	C. W. Rice	8.15 p.m.
10	Illuminating Engineering Society	P. S. Millar	8.15 p.m.
11	American Institute of Electrical Engineers	R. W. Pope	8.00 p.m.
15	New York Telephone Society	T. H. Lawrence	8.00 p.m.
17–18	Society of Naval Architects and Marine Engineers	W. J. Baxter	All day
18	New York Railroad Club	H. D. Vought	8.15 p.m.
23	Municipal Engineers of New York	C. D. Pollock	8.15 p.m.
December			
1	Blue Room Engineering Society	W. D. Sprague	8.15 p.m.
6, 7, 8, 9	American Society Mechanical Engineers	C. W. Rice	All day
7	Wireless Institute	S. L. Williams	8.00 p.m.
8	Illuminating Engineering Society	P. S. Millar	8.15 p.m.
9	American Society Electrical Engineers	R. W. Pope	8.00 p.m.
16	New York Railroad Club	H. D. Vought	8.15 p.m.
20	New York Telephone Society	T. H. Lawrence	8.15 p.m.
28	Municipal Engineers of New York	C. D. Pollock	8.15 p.m

CURRENT BOOKS

THE CONSTRUCTION OF GRAPHICAL CHARTS. By John B. Peddle. *New York, McGraw-Hill Book Co., 1910.* Cloth, 8vo, 109 pp., illustrated. Price, $1.50.

Contents: Charts Plotted on Rectangular Co-ordinates; The Alinement Chart; Alinement Charts for More than Three Variables; The Hexagonal Index Charts; Proportional Chart; Empirical Equations; Stereographic Charts and Solid Models.

ELECTRIC MOTORS, CONTINUOUS, POLYPHASE AND SINGLE-PHASE MOTORS. THEIR THEORY AND CONSTRUCTION. By Henry M. Hobart. Second edition, revised and enlarged. *New York, The Macmillan Co., 1910.* Cloth, 8vo, 748 pp., 798 illustrations. Price, $5.50.

Contents: Part I. Continuous Motors: Introductory; General Discussion of Continuous Motors; Data for Motor Designing; Types of Armature Windings; Compound-Wound, Series, and Shunt Motors; Hopkinson Method of Motor Testing; Commutator Design; Comparative Designs for 35-h.p. Motor; Examples of Shunt Motor Designs by Different Manufacturers; Examples of Designs of Compound Motors; Interpole Motors; Variable-Speed Motors; Traction Motors; Part II. Polyphase Motors: Desirability of Using Polyphase Electricity; Methods of Starting Induction Motors; Comparisons Between Induction and Continuous Motors; The Design of Three-Phase Induction Motors; the Circle Diagram and its Practical Applications; The Torque of Induction Motors; The Circle Coefficient; Heating of Induction Motors; Calculations of I^2 R Loss in Squirrel-Cage Induction Motor Design; Examples of Three-Phase, Slip-Ring Induction Motors of Small Outputs; Examples of Three-Phase Induction Motor Designs Employing Wound Rotors, Having Medium Outputs; Examples of Three-Phase Induction Motor Designs, Employing Wound Rotors, Having Large Outputs; The Hunt Squirrel Cage; Variable-Speed Polyphase Motor; The Design of Small Motors for Manufacture in Large Quantities; Cost and Weight Coefficients of Induction Motors; Part III. Single-Phase Motors: Introductory; The Single-Phase Induction Motor without a Commutator; The Single-Phase Series Motor; The Repulsion Motor; The Compensated Repulsion Motor; Other Single-Phase Railway Motors; The Déri Repulsion Motor; Creedy's Design of an Atkinson Repulsion Motor; The Wagner Single-Phase Commutator Motor; The Schüler Motor; Variable-Pole Repulsion Induction Single-Phase Commutator Motor; Shunt Single-Phase Commutator Motor.

THE MECHANICAL ENGINEERS POCKET-BOOK. A Reference-Book of Rules, Tables, Data, and Formulae, for the Use of Engineers, Mechanics, and Students. By William Kent. 8th ed., rewritten. *New York, John Wiley & Sons, 1910.* Morocco, pocket-book size, 1461 pp. Price, $5 net.

Contents: Mathematics: Arithemetic, Weights and Measures, Algebra, Mensuration, Plane Surfaces, Mensuration, Solid Bodies, Plane Trigonometry, Analytical Geometry, Differential Calculus, Slide Rule, Logarithmic Ruled Paper, Mathematical Tables, Materials, Miscellaneous Materials, Strength of Materials, Alloys, Ropes and Cables, Springs, Riveted Joints, Iron and Steel, Steel; Mechanics; Elements, Stresses in Framed Structures; Heat; Physical Properties of Gases; Air: Flow of Air, Wind, Compressed Air, Fans and Blowers; Heating and Ventilation; Water: Hydraulics, Flow of Water, Water-Power, Water Wheels, Turbine Wheels, The Power of Ocean Waves, Pumps, Hydraulic Pressure Transmission; Fuel: Liquid Fuel, Fuel Gas, Acetylene and Calcium Carbide, Illuminating Gas; Steam: Flow of Steam, Steam-Pipes; The Steam Boiler; Strength of Steam-Boilers; Boiler Attachments, Furnaces, etc., Safety-Valves, The Injector, Feed-Water Heaters, Steam

Separators, Determination of Moisture in Steam, Chimneys; The Steam Engine: Compound Engines, Steam-Engine Economy, Dimensions of Parts of Engines, Fly-Wheels, Slide-Valve, Governors, Condensers, Air-Pumps, Circulating-Pumps, etc., Rotary Steam Engines, Steam Turbines, Naphtha Engines, Hot-Air Engines, Internal Combustion Engines; Locomotives; Shafting; Pulleys; Belting; Gearing: Forms of Teeth, Strength of Gear Teeth; Hoisting and Conveying, Cranes, Coal-Handling Machinery, Wire-Rope Haulage; Wire-Rope Transmission; Rope Driving; Friction and Lubrication: Friction Brakes and Friction Clutches, Lubrication; The Foundry; The Machine Shop: Abrasive Processes, Various Tools and Processes; Dynamometers; Ice Making or Refrigerating Machines; Marine Engineering: Screw-Propeller, Marine Practice, Paddle-Wheel, Jet Propulsion; Construction of Buildings: Foundations, Masonry, Beams and Girders, Walls, Floors, Columns and Posts; Electrical Engineering: Electrical Resistance, Direct Electric Currents, Electric Transmission, Direct-Currents, Electric Railways, Electric Lighting, Illumination, Electric Batteries, Magnetic Circuit, Dynamo-Electric Machines, Alternating Currents, Alternating Current Circuits, Transformers, Converters, etc., Electric Motors, Alternating Current Motors, Sizes of Electric Generators and Motors.

RUSSIAN TURKESTAN AND ITS PRODUCTS. By N. J. Malahowski. *St. Petersburg, 1910.*

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS. Written and compiled by a staff of specialists. 3d ed., revised and enlarged. *New York, McGraw-Hill Book Co., 1910.* Morocco, pocket-book size, 1497 pp., reference tables. Price, $4 net.

Contents: Units; Electric, magnetic and dielectric currents; Measurements and Measuring Apparatus; Properties of Materials; Magnets, Restorers, Condensers and Reactors; Transformers and Converters; Electric Generators; Electric Motors; Batteries; Central Stations; Transmission and Distribution; Illumination; Electric Traction; Electrochemistry; Telephony; Telegraphy; Miscellaneous Applications; Wiring; Standardization Rules; Tables and Statistics.

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1910

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MEETINGS OF THE SOCIETY

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WM. H. BRYAN (1) — CHAS. E. LUCKE (3)
H. DEB. PARSONS (4)

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INSTITUTION	BRANCH AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	CORRESPONDING SECRETARY
	1908			
Stevens Inst. of Tech. Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	C. C. Allen	C. F. Hirschfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	G. F. Gebhardt	F. E. Wernick	W. E. Thomas
Leland Stanford Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	J. B. Bubb	H. H. Blee
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	H. A. Houston	J. W. Barr
University of Kansas, Lawrence, Kan.	March 9	P. F. Walker	C. E. Johnson	C. A. Swiggett
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	B. L. Keown	C. S. Huntington
Penna. State College, State College, Pa.	November 9	J. P. Jackson	W. E. Heibel	G. M. Forker
Columbia University, New York.	November 9	Chas. E. Lucke	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Morrill Mackenzie	Foster Russell
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	H. B. Cook	C. J. Malone
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	A. Mac Arthur	A. Wegner
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. V. Aycock	Osmer Edgar
Univ. of Nebraska, Lincoln, Neb.	December 7	C. R. Richards	W. J. Wholenberg	W. H. Burleigh
	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett	H. N. Danforth	A. H. Blaisdell
Univ. of Arkansas, Fayetteville, Ark.	April 12	B. N. Wilson	C. B. Boles	W. Q. Williams
Yale University, New Haven, Conn.	October 11			W. Roy Manny